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Handbook of Energetic Materials for Weapons Systems Including Ballistic and Cruise Missiles

Gordon Boezer
L. Kirk Lewis
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FOREWORD

The handbook is a distillation in data sheet format of information about substances not widely available outside of the United States and its NATO allies that are considered to be critical for the development of advanced weapons and munitions systems. The document summarizes, updates and, to some degree, supersedes IDA Memorandum Report M-456, *Foreign Capabilities Assessment of Energetic Materials Technology* (April 1988); IDA Paper P-2391, *Energetic Materials and Devices Technology Guide and Foreign Technology Assessment* (October 1990); and IDA Document D-1268, *Munitions Devices and Energetic Materials Technology* (May 1994).

It is intended as a desktop handbook for Customs Officers; Licensing, Security and Classification officials; and Research, Development and Engineering personnel. There continue to be many omissions and gaps in day-to-day knowledge of the listed substances. The template has been designed to permit the ready expansion or elimination of entries as appropriate.

It is apparent even from the summary data sheets that many of the listed energetic materials are increasingly available, or at least offered for sale, both within NATO and developing countries. This trend was noted in previous reports. These materials are listed because they represent the cutting edge of products covered by the U.S. Military Lists (USML), International Military List (IML), Nuclear Related Dual Use List (NDUL), and Missile Technology Control Regime (MTCR). What is also apparent is the widespread copying or reverse engineering of both U.S./NATO concepts and designs by other countries.

Although not obvious, it is important to recognize that numerous countries are able to produce other, less advanced munitions and weapons systems, which are covered by the control lists, but which are not considered to represent cutting edge technology even though their quality may meet or exceed U.S. standards for similar items. In addition, there is evidence that several major U.S. defense contractors today have capabilities to produce both a wider range of munitions and munitions of considerably greater complexity than is customarily associated with pre-1960 Government-owned, Contractor-operated (GOCO) plants and defense contractors. The ability of the U.S. contractors to compete in inter-

national markets is, however, constrained by the requirements for export licenses for comparatively unsophisticated, standard quality products under existing laws and policies.

Also not discussed explicitly is the impact on U.S. production efficiency of current environmental and demilitarization initiatives. Among the options to achieve current environmental objectives has to be the import into the U.S. of selected bulk materials that are widely available, and whose manufacture is the source of industrial pollution. Economic rather than environmental issues have already created precedents for such an approach, as for example the import of military grades of TNT, and commercial grades of RDX. The data sheets indicate, however, that even in respect to the non-standard, critical materials there are instances of capability or business moved overseas. Such occurrences mean that the U.S. must now import the substances, even if it then has to refine the products to meet U.S./NATO military requirements.

Further options to current environmental constraints center on the substitution of polymeric fuels and chlorine-free oxidizers (derived from widely available fertilizers) for more tightly controlled substances, such as ammonium perchlorate and HMX missile propellant ingredients. Successful implementation of such options could have a significant impact on the availability to potential proliferants of viable missile propellant technology.

PREFACE

This handbook and its accompanying spreadsheet format were prepared for the Defense Technology Security Administration under a task for the Assessment of Energetic Materials Technology Essential to the Development of Ballistic and Cruise Missiles.

The Export Administration Act of 1979, as amended, was continued indefinitely by Executive Order #12924 of August 19, 1994. The Act directs the Secretary of Defense and other appropriate departments to identify goods and technologies for the inclusion in U.S. Control Lists. The Secretary of Defense is assigned the primary responsibility for identifying critical technologies which, if applied by certain countries, would permit significant advances in their military capabilities.

The technologies so identified consist of lists and coordinated statements of products and capabilities deemed to be critical for continuing U.S. military superiority. They also provide a basis for assessing both the proliferation of capabilities that could pose a threat to U.S. national security and the economic security implications of export controls.

The assessments become a basis for U.S. proposals for export control in the New Forum, the MTCR, the Nuclear Suppliers Group, the Australia Group, and other non-proliferation regimes. The compiled information is also a technical reference for:

- Licensing and export control by Customs officials, DoD, and the Departments of State, Commerce, and Energy
- Release and distribution of contractor reports and the scientific papers by government industry and academia
- Intelligence collection

Among the technologies determined to fall under the Act are those covering the substances that are variously described as energetic materials or military explosives. President Bush's Executive Order #12735, 16 November 1990, on chemical and biological weapons proliferation, highlighted the importance of international controls on weapons of mass destruction. The Gulf War, and the revelations of the impact imported technologies had on the development of Iraq's nuclear, chemical and biological programs, and missile delivery systems, reaffirmed the need to address the unprecedented proliferation of

weapons of mass destruction. The delivery, dissemination, or lethality of weapons of mass destruction would scarcely be possible without the incorporation of one or more of the energetic materials covered by the listed technology. They are also essential components of a broad range of tactical munitions and weapons systems that are at the cutting edge of U.S. military capabilities.

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CONTENTS

INTRODUCTION

This handbook provides supporting information about energetic materials (or military explosives) that are subject to export control in accordance with the New Forum (formerly COCOM) International and U.S. Military Lists and the MTCR. The information is given in tables and data sheets and is intended as an alternative to a compilation of the same information in a companion, computer spreadsheet format. Both versions update, supplement, and present in a more accessible manner the extensive information presented in IDA Paper P-2391 and earlier reports; both formats permit incremental updating of the data base.

In both versions the three lists of controlled substance have been consolidated into one list, but Table 1, Controlled Substance Regulation Matrix, in the handbook also separately identifies which list controls the specific substances. The data sheets have been updated to emphasize clearer definitions of the names and synonyms of listed substances and to provide the following information on the substances:

- CAS numbers
- Molecular structures and chemical formulas
- Qualities subject to control
- Process, packaging, and manufacturing techniques (where not classified or proprietary)
- Points of contact for production or developmental items
- Military and civil uses
- Foreign availability
- Notes and references useful for assessing the status or validity of current listings

The flexible template adopted for the data sheets is intended to facilitate recording of further notes and the periodic updating of entries as new information becomes available.

In this handbook each substance or group of substances listed in the control documents is provided with a data sheet or a set of data sheets arranged in alphanumeric order. In Table 1 the substances are arranged in approximately the order that they appear in the

control lists. However, it was not possible to follow the order precisely, because the substances are not entered in the same sequence in the different lists, and some substances do not appear in all the lists. Furthermore, some generalized entries in the lists have been supplemented to give illustrative examples of specific substances that are covered by the general statements.

The names used to define the substances may differ marginally from those listed in the control documents. They are, however, the preferred names recommended by members of a government/industry advisory group. During the course of the review a few additional substances were identified as candidates for listing in future updates of control lists; outline data sheets for these substances are included in the handbook for completeness. An exception to members' recommendations occurs in respect to the numbering of the constituents of compounds according to standard IUPAC notation. The present entries in the control lists sometimes use nomenclature that includes the numbering (such as 2,4,6-trinitrotoluene); other entries omit the numbering, thus presenting simpler entries (such as cyclotetramethylene-tetranitramine). The differences are largely historical; substances more recently introduced into the lists tend to include numbered constituents; older, more well-established military explosives are unnumbered. Consistency suggests that all should either be numbered or unnumbered.

There are synonyms or trade names for most of the listed substances. For immediate purposes, where not already so listed, numbered constituents have been included among synonyms. A standard search routine used in conjunction with the spreadsheet format permits these alternatives to be readily found within the context of the preferred names.

Entries in the different control lists also do not always cover the same "qualities" or grades of a particular substance. In the spreadsheet version of the data base, separate entries are provided for each listed quality of a controlled substance, where different qualities are to be found in different control lists. However, the different qualities have been combined under their common substance name in the handbook data sheets.

SUMMARY

This document presents information about substances that are considered critical to the development of advanced weapons and munitions systems. Intended as a handbook for Customs officers; licensing, security, and classification officials; and research, development, and engineering personnel, this document lists regulated energetic materials in two ways.

First, a table presents, in matrix form, a list of controlled substances and compounds; their applicable regulations, if any, from the New Forum International Military List (NFML), the U.S. Munitions List (USML), and the Missile Technology Control Regime (MTCR); and the quality controlled. Second, data sheets emphasize clearer definition of the names and synonyms of the listed substances as well as the following information:

- CAS numbers
- Molecular structures and chemical formulas
- qualities subject to control
- process, packaging, and manufacturing techniques (when not classified for proprietary
- points of contact for production or developmental items
- military and civilian uses
- foreign availability
- notes and references useful for assessing the status or validity of current listings

"Energetic materials" or "military explosives" are collective terms for high explosives, propellants, and pyrotechnics. Since World War II the production of standard energetic materials (e.g., TNT, RDX, HMX) and their loading into conventional munitions characteristically has been conducted in the 26 or more U.S. Army Ammunition Plants or in Government-owned, Contractor-operated (GOCO) facilities. As essential stockpiles have accrued, the requirement for the capabilities has been steadily reduced so that by the turn of the century it is anticipated that no more than 9 or 10 will be in operation. During

the past few years, even when occasional low level requirements have surfaced, it has been found more practical to make foreign purchases than to reactivate domestic facilities.

The development of smart munitions, ballistic missiles, and cruise missiles has further reduced demand for standard explosives. The newer systems, being fewer and more accurate, both lower the consumption of energetic materials in combat environments and introduce many of the newer, higher quality materials listed in this handbook. The materials are increasingly being developed and produced in private industry rather than in government facilities, but here again, demand and cost pressures have restricted the vitality of the domestic production base, such as for example the discontinuation of production of catocene in the United States.

I. ENERGETIC MATERIALS TECHNOLOGY

A. INTRODUCTION

The following discussion is intended as a primer on energetic materials technology. Technical terms that have a particular meaning in this context are defined in Appendix A. Also discussed are some of the relevant technical considerations used by government/ industry experts in assessing elements of the technology appropriate to the U.S. and international export controls.

Energetic materials technology is concerned with (1) the formulation, production, and testing of high explosives, propellants, and pyrotechnics, (2) their incorporation (or loading) into conventional munitions and weapons systems, such as bombs, projectiles, warheads, land and sea mines, torpedoes, and tactical missiles, and (3) their incorporation into the propulsion systems for guns and strategic missiles. A few of the materials are also used in nuclear warheads or to provide the energy required to disperse rapidly the chemical/biological agents from chemical weapons/biological weapons munitions. Relevant systems include both ballistic and cruise missiles.

In general, the discussion is concerned with a class of materials whose performance parameters are at or above the minimum necessary to ensure the continuing superior performance for U.S. military systems.

B. WHAT ARE CONSIDERED ENERGETIC MATERIALS?

Energetic materials or military explosives are collective terms for high explosives, propellants, and pyrotechnics. Although several well-known energetic materials such as trinitrotoluene (TNT), lead azide, or nitrocellulose are essentially composed of a single ingredient, most modern energetic materials are formulations of several ingredients, and it is these ingredients which are the subject of the data sheets presented in this handbook.

The energetic materials may be transported as finished charges in subsystems and components of missile systems, such as warhead sections, munitions dispensers, submunitions, launch and propulsion subsystems, and fuzes, or in guidance sections and associated control surfaces. Alternatively, they may be shipped as bulk quantities for

incorporation into such devices or for re-sale to third parties. Further aspects of shipment in bulk are discussed below.

When incorporated as cast, pressed, or extruded charges in the various subsystems and components, the different energetic materials make possible the range, guidance, maneuverability, payload, and lethality of the most advanced U.S./NATO systems.

Energetic materials are intended to react chemically as fuels and/or oxidizers to release the energy required for their application. A single ingredient may function entirely as a fuel (for example, aluminum) or as an oxidizer (for example, fluorine), but more generally an ingredient may contain both fuel and oxidizer components within its singular molecular structure (e.g., ammonium perchlorate). Thus, it is possible for a single substance to serve as both a fuel and an oxidizer, and such an ingredient may be loosely termed by engineers to be either a fuel or an oxidizer depending on the other substances of a formulation and on the predominant role it plays during its reaction.

Normally, to achieve the highest rates of reaction, such as occur during the detonation of a high explosive, the main ingredient must incorporate both fuel and oxidizer components in close proximity within a single molecular structure (such as cyclotetra-methylene-tetranitramine, HMX). The oxygen-balance of such a substance may still be optimized by the addition of a second oxygen-rich or oxygen-deficient ingredient; such formulations (sometimes of identical composition) may function either as high explosives or as propellants (also known as low explosives) depending on the temperature and pressure (or shock) profile used to ignite or initiate the reaction.

In addition to chemical explosive ingredients, formulations may include additives and stabilizers that are also manufactured primarily for military purposes. Almost all listed substances require available commercial, industrial chemicals (such as nitric acid) for their production; others also require unique precursors that must be manufactured specially for the production of the listed substances.

C. GENERAL CONTROL PARAMETERS FOR ENERGETIC MATERIALS

Energetic materials are rarely selected for military use on the basis of a single parameter. Following an assessment of a range of properties and characteristics, the listed substances are those which have been found to provide superior operational effectiveness for one or more modern applications in missile systems. In addition to such performance requirements as detonation velocity, specific impulse, spectral intensity, or sensitivity, all the materials must meet minimum qualification requirements relating to their safety,

producibility, dimensional stability, shelf life, cost, and availability, to name but a few of the criteria by which ingredients or formulations are assessed.

In general, however, each of the listed substances, either of itself or as an ingredient of a qualified formulation, meets one or more of the following criteria and is able to function as:

- A high explosive with a detonation velocity greater than 8,700 m/s or a detonation pressure greater than 340 kilobars;
- An organic high explosive yielding detonation pressures of 250 kilobars or greater that will remain stable at temperatures of 523 K (250 °C) or higher for periods of 5 minutes or longer;
- A UN Class 1.1 solid propellant with a theoretical specific impulse (under standard conditions) greater than 250 seconds for non-metallized, or greater than 270 seconds for aluminized compositions;
- A UN Class 1.3 solid propellant with a theoretical specific impulse greater than 230 seconds for non-halogenized, 250 seconds for non-metallized, and 266 seconds for metallized compositions;
- An energetic material that can sustain a steady-state burning rate greater than 38 mm per second under standard conditions of 68.9 bar pressure and 294 K (21 °C);
- A gun propellant having a force constant greater than 1,200 kJ/kg; or
- An elastomer-modified, cast double based propellant (EMCDB) with an extensibility at maximum stress greater than 5 percent at 233 K (– 40 °C).

(Note: UN hazard classifications are described starting on page I-8.)

D. PRODUCTION ISSUES

Characteristically, since World War II the production of standard energetic materials (e.g., TNT, RDX, HMX) and their loading into conventional munitions has been conducted in the 26 or more U.S. Army Ammunition Plants, or Government-owned, Contractor-operated (GOCO) facilities. As essential stockpiles have accrued, the requirement for the capabilities has been steadily reduced so that by the turn of the century it is anticipated that no more than 9 or 10 plants or facilities will continue to be in operation. During the past few years, even when occasional low level requirements have surfaced, it has been found more practical to make foreign purchases than to reactivate domestic facilities. Examples include the purchase of TNT from Canada or of RDX from Australia.

The development of smart munitions, ballistic missiles, and cruise missiles has further reduced demand for standard explosives. The newer systems, being fewer and more accurate, both lower the consumption of energetic materials in combat environments and introduce many of the newer, higher quality materials listed in this handbook. The materials are increasingly being developed and produced in private industry rather than in government facilities, but here again, demand and cost pressures have restricted the vitality of the domestic production base, such as for example the discontinuation of production of catocene in the United States.

Turnkey plants are designed and sold for many of the standard explosives that are used in the defense industry. Sometimes the same plant can be used to produce any one of several substances by suitable adjustment of the process parameters. The widely available continuous plants for the production of nitroglycerin are an example. At the other extreme are batch– or continuously operated pilot plants for the production of the more advanced substances listed in this handbook. These plants are normally assembled from reaction vessels, product scrubbing and recrystallization units, and materials transfer equipment obtained as special designs on a one-off basis from several different suppliers.

1. Production Quantities

The quantities of material required for different purposes and applications vary considerably. The state-of-the-art in synthesizing new or advanced substances is such that a few kilograms or even grams may be all that are necessary to explore the military potential of substances being introduced for the first time. If competent chemists skilled in organic synthesis are available in a country, even the knowledge that a substance exists may be sufficient to permit a manufacturing process to be quickly devised. Since most energetic materials are formulated from a number of ingredients, if a particular substance represents only a small proportion of an overall composition, a relatively small quantity may again be all that is required.

Substances used to ignite or initiate explosive reactions are not normally required in large quantities. Components, such as fuzes, may require less than a gram of material to be effective. In addition, some ingredients are not explosives in themselves, although they may be fuels. These materials lower the power of compositions, and it is necessary to limit the amounts incorporated in order to retain an adequate explosive potential for an overall formulation.

The usage rates of systems vary widely. High-use, lower-cost items, such as conventional bombs and gun-launched projectiles, may so dominate the requirements for substances (up to millions of pounds per day have been typical of U.S./NATO wartime usage rates) that they essentially establish the production capacities of plants and determine the quality of the product that is stockpiled as the norm. Higher quality material that is essential for cost-effective application in more advanced, low-use items then requires separate chemical or physical processing in small capacity plants. The introduction of smart, brilliant, or sentient munitions will modify (reduce) requirements for the high-use materials. It is conceivable that the reduction in requirements will so nullify the current advantage that the United States enjoys from its high production capacities that even developing nations, if they have not already done so, will readily acquire a challenging capability for the production of the substances. Such a trend may reduce the requirement for the United States to develop large capacities for the more advanced substances, and will place additional emphasis on the need for the U.S./NATO to safeguard the more advanced technology, which currently it alone can produce in any quantity.

Peacetime production requirements are normally low, matched primarily to stockpile requirements and the need to replenish the consumption associated with training personnel and with reliability and maintenance programs. Yet plants traditionally have had to be able to meet the surge requirements that accompany the outbreak of hostilities. Mothballing of plants is frustrated by the deterioration of equipment once it has been subjected to the corrosive reactants used in most of the relevant processes. Capital investment is also difficult to obtain for facilities that have few, if any, domestic applications. Typically, therefore, the peacetime production rates in most nations having manufacturing capabilities are augmented by exporting to other nonproducing countries. Alternatively, the plant capacities are moderated, and during times of national emergency, the products are supplemented with low-cost, less effective substances that are available in large quantities from the domestic economy. Commercial explosives and fertilizers are commonly used as supplements even though they may not be optimal for military purposes.

2. Product Quality

Bulk materials acquired for development or for application in missile systems normally require further processing prior to their incorporation in more complex formulations. The following are considerations that determine the quality of such materials:

Purity Required—The ultimate in purity is not always, if ever, required; in some instances, impurities are selectively retained, as these give desirable properties to the products. Normally the impurity levels must, however, be reproducible.

Grade Required—Many substances are stockpiled in different grades, usually assessed in terms of particle size fractions or other characteristics of crystal morphology. The availability of a grade may determine the quality of material used in a formulation; the particular grade may not necessarily be optimal for military purposes or the only grade that would merit use for the same application. This may occur even if U.S.-preferred grades are available.

Relevant Specifications and Standards—The quality of materials that are stockpiled are defined by U.S. Military Specifications and related NATO Specifications; waivers can be obtained if deficiencies are deemed not to be significant for the intended application. Bulk materials used in U.S./NATO munitions and weapons are required to meet MILSTDs for safety in handling, storage, and transportation, and the functional (or performance) requirements within defined climatic extremes (generally – 65 °F to + 165 °F). The requirements may not be considered necessary by other countries with fewer concerns about safety, less demanding climatic considerations, and a toleration of lower reliability. Munitions design fixes can sometimes be introduced to accommodate problems that arise from the use of lower quality materials; alternative procedures for loading or fabricating explosives may be less demanding of material quality.

Reprocessing Effects—Stockpiled materials are commonly reprocessed to improve their quality when required for high-cost, precision munitions and high-performance missile systems. Such processing is usually conducted in the U.S. and other NATO countries at different facilities than those used to manufacture the bulk materials.

E. DIFFERENCES IN COMMERCIAL AND MILITARY USE OF ENERGETIC MATERIALS

The relevant technology is of limited civil use, and a normal presumption is that requests for bulk quantities of any of the substances are related to intended military applications. Likewise, requests for data on their properties, manufacturing processes, or production plants and equipment may be presumed to have a similar purpose. Technology and materials that are widely available in international markets are not listed, except insofar as they may relate to proliferation issues.

Energetic materials used for military purposes are more expensive, more powerful, have extended shelf lives, and tend to be more hazardous than the substances used for domestic and international commercial applications. An exception is the selective use of

listed materials for oil well stimulation. Even though they are manufactured in very large quantities, commercial explosives are not used by the military, except by military engineers for civil works or during major hostilities.

F. SHIPPING AND LABELING OF ENERGETIC MATERIALS

Fire and explosion hazards (and often toxicity hazards) are associated with almost all the listed materials. Specific labeling and storage requirements are imposed for safe shipping, handling, and long term storage of the materials.

The transport of dangerous goods is regulated by most developed countries to reduce the likelihood of injury to persons and damage to property. Regulations are normally framed so as not to impede the movement of goods; but some materials are considered too dangerous to transport, and movement in bulk is restricted to the premises used for their manufacture. Approval for the transport of such materials may still be obtained, however, if quantities are reduced to small lots or artifacts and shipped in non-propagating packs. The rigor with which such constraints are imposed differs from country to country, but most developed countries subscribe to United Nations recommendations or to international marine and air transportation regulations, and have compatible transportation safety regulations for domestic railroad and vehicular shipments of explosive substances. Because of the constraints on public transportation of materials, among NATO allies military aircraft are often used for the shipment of special purchases of selected materials.

Packaging requirements vary considerably depending on the sensitivity of the material and its physical form (i.e., whether it is a solid, liquid, or gas at transportation and storage temperatures and pressures). Diluent, solvent, or de-sensitizing liquids such as water or alcohol protect the materials both against heat and shock and from adverse environmental conditions such as humidity, oxygen, carbon dioxide, etc. Distinctive labeling is required for all shipments of listed substances and articles or commodities that contain them. Such labeling is an aid in the identification of shipments being conducted in accord with regulations.

Normally, in English-speaking countries such packages or containers are required to be labeled "Explosive," followed by an appropriate subclassification, such as "high explosive," "propellant," etc. NATO countries did not adopt the term "energetic materials" to describe such goods, because the hazard implications of the term "explosive" are easily recognizable from the equivalent French, German, Spanish, Italian, etc., words to be

found on packages originating in those countries. The term "military explosives" or simply "explosive" is used instead in U.S. and in New Forum control documents and is defined to be consistent with UN definitions. The packages may be labeled "explosive substance" (as listed in this handbook) or "explosive article" if the contents are items that contain the listed substances, such as fuzes, warheads, decoys, etc.

The UN *Recommendations for the Transport of Dangerous Goods* (UN Publication ST/SG/AC.10/1/Rev.8, New York, NY 1993) gives guidelines for the classification, packaging and labeling of substances. Specific substances or qualities of a substance are classified in terms of the hazard potential they represent. Test procedures and packaging are recommended for the classification and shipment of each class or subclass of substance or commodity.

The following summarizes the UN hazard classification for substances listed in this handbook, but it should be noted that the transport of explosive substances which are unduly sensitive or so reactive as to be subject to spontaneous reaction is prohibited. Some listed substances (e.g., liquid oxidizers) and some other substances no longer listed in control documents (e.g., triethylaluminum) come close to this constraint. Also many of the substances are transported so rarely that they are not listed in the UN reference; these substances nevertheless have a UN or equivalent classification determined by defense or trade testing laboratories in accordance with recognized procedures.

It is the objective of on-going U.S./NATO developments to produce missiles having more survivable warhead and propulsion subsystems that may be classified in the lower (1.3–1.6) divisions of Class 1. Such advances are achieved by improved structural designs, by incorporation of some of the less sensitive among listed substances, or by both approaches applied together.

1. Hazard Class 1—Explosives

Class 1 comprises

(a) Explosive substances, except those that are too dangerous to transport or those for which the predominant hazard is appropriate to another class. (A substance which is not itself an explosive, but which can form an explosive atmosphere of gas, vapor or dust is not included in Class 1.)

(b) Explosive articles, except devices containing explosive substances in such quantity or of such a character that their inadvertent or accidental ignition or initiation during transport would not cause any effect external to the device either by projection, fire, smoke, heat or loud noise.

(c) Substances and articles not mentioned under (a) and (b) which are manufactured with a view to producing a practical, explosive or pyrotechnic effect.

For the purpose of these Recommendations, the following definitions apply.

(a) An explosive substance is a solid or liquid substance (or a mixture of substances) which is in itself capable by chemical reaction of producing gas at such a temperature and pressure and at such a speed as to cause damage to the surroundings. Pyrotechnic substances are included even when they do not involve gases.

(b) A pyrotechnic substance is a substance or a mixture of substances designed to produce an effect by heat, light, sound, gas or smoke or a combination of these as the result of non-detonative, self-sustaining exothermic chemical reactions.

Class 1 is divided into six divisions:

- Division 1.1, Substances and articles which have a mass explosion hazard (a mass explosion is one which affects almost the entire load virtually instantaneously.)
- Division 1.2, Substances and articles which have a projection hazard but not a mass explosion hazard.
- Division 1.3, Substances and articles which have a fire hazard and either a minor blast hazard or a minor projection hazard or both, but not a mass explosion hazard.

  This division comprises substances and articles which give rise to considerable radiant heat, or which burn one after another, producing minor blast or projection effects or both.

- Division 1.4, Substances and articles which present no significant hazard.

  This division comprises substances and articles which present only a small hazard in the event of ignition or initiation during transport. The effects are largely confined to the package and no projection of fragments of appreciable size or range is to be expected. An external fire should not cause virtually instantaneous explosion of almost the entire contents of the package.

  Substances and articles of may be compatible with this division if they are so packaged or designed that any hazardous effects arising from accidental functioning are confined within the package unless the package has been degraded by fire, in which case all blast or projection effects are limited to the extent that they do not significantly hinder fire-fighting or other emergency response efforts in the immediate vicinity of the package.

- Division 1.5, Very insensitive substances which have a mass explosion hazard.

  This division comprises substances which have a mass explosion hazard but are so insensitive that there is very little probability of initiation or of transition from burning to detonation under normal conditions of transport. The probability of transition from burning to detonation is greater when large quantities are carried in a ship.

- Division 1.6, Extremely insensitive articles which do not have a mass explosion hazard.

  This division comprises articles which contain only extremely insensitive detonating substances and which demonstrate a negligible probability of accidental initiation or propagation. The risk from articles of Division 1.6 is limited to the explosion of a single article.

2. Hazard Class 2—Gases

Substances of Class 2 are assigned to one of three divisions based on the primary hazard of the gas during transport.

- Division 2.1, Flammable gases.

  Gases which at 20 °C and a standard pressure of 101.3 kPa either are ignitable when in a mixture of 13% or less by volume with air; or have a flammable range with air of at least 12% regardless of the lower flammable limit.

- Division 2.2, Nonflammable, nontoxic gases.

  Gases which are transported at a pressure not less than 280 kPa at 20 °C, or as refrigerated liquids, and which are asphyxiant gases (which dilute or replace the oxygen normally in the atmosphere), or are oxidizing gases which may, generally by providing oxygen, cause or contribute to the combustion of other material more than air; or do not come under the other divisions.

- Division 2.3, Toxic gases.

3. Hazard Class 3—Flammable liquids

4. Hazard Class 4—Flammable solids

The class includes substances liable to spontaneous combustion, and substances which in contact with water emit flammable gases; it comprises

- Division 4.1, Flammable solids.

Solids which, under conditions encountered in transport, are readily combustible or may cause or contribute to fire through friction or self-reaction; desensitized explosives which may explode if not diluted sufficiently.

- Division 4.2, Substances liable to spontaneous combustion.

  Substances which are liable to spontaneous heating under normal conditions encountered in transport, or to heating up on contact with air, and being then liable to catch fire.

- Division 4.3, Substances which in contact with water emit flammable gases.

  Substances which, by interaction with water, are liable to become spontaneously flammable or to give off flammable gases in dangerous quantities.

5. Hazard Class 5—Oxidizing substances; organic peroxides

This class comprises

- Division 5.1, Oxidizing substances.

  Substances which, while in themselves not necessarily combustible, may, generally by yielding oxygen, cause, or contribute to, the combustion of other material.

- Division 5.2, Organic peroxides.

  Organic substances which contain the bivalent -0-0- structure and may be considered derivatives of hydrogen peroxide, where one or both of the hydrogen atoms have been replaced by organic radicals.

  Organic peroxides are thermally unstable substances, which may undergo exothermic self-accelerating decomposition. In addition, they may have one or more of the following properties:

  - *liable to explosive decomposition*
  - *burn rapidly*
  - *sensitive to impact or friction*
  - *react dangerously with other substances*
  - *cause damage to the eyes.*

6. Hazard Class 6—Toxic and infectious substances

This class comprises

- Division 6.1, Toxic substances.

  Substances which are liable either to cause death or serious injury if swallowed, inhaled, or contact the skin.

Note that among listed substances this hazard often takes precedence over explosion hazards.

- Division 6.2, Infectious substances.

7. Hazard Class 8—Corrosive substances

Substances which by chemical action cause damage when in contact with living tissue; or in the case of leakage, materially damage or destroy other goods or the means of transport.

II. EXPORT CONTROL REGIMES

Energetic materials are controlled for export purpose by three principal regimes:

(1) New Forum International Military List (NF ML or ML), specifically by Item 8 of the list headed: Military explosives, fuels, and liquid oxidizers ... and additives, and precursors for military explosives and fuels; 23 February 1995

(2) U.S. Munitions List (USML), formerly known as the International Traffic in Arms Regulations (ITAR); specifically Category V: Explosives, propellants, incendiary agents, and their constituents; November 1993 and

(3) Missile Technology Control Regime (MTCR), Equipment and Technology Annex 4 (referenced to Annex 1.C of IDA draft realignment dated 1 March 1994).

A fourth list, the Nuclear Related Dual Use List (NDUL), also lists a few substances of particular relevance to nuclear warhead technology.

In this handbook substances or groups of substances listed in the control documents are provided with a data sheet or set of data sheets organized in alphanumeric sequence. An index is provided to help in locating substances, and a glossary is provided to identify substances that are often called by acronyms. The names used to define the substances may differ marginally from those listed in the control documents but are the preferred names suggested by a government/industry advisory group. A separate index is provided to assist in locating synonyms for the preferred names.

In accordance with the control regimes, the substances in Table 1 are arranged in approximately the order that they appear in the control lists, showing which document or documents controls the particular substances. It is not possible to follow the order precisely, because the substances are not entered in the same sequence in the different lists, and some substances do not appear in all the lists. Furthermore, some generalized entries in the lists have been supplemented to give illustrative examples of specific substances that are covered by the general statements.

It should be noted that the USML also lists some widely available standard explosives, such as nitroglycerin (NG), trinitrotoluene (TNT), trinitrophenylmethylnitramine (Tetryl), and penta-erythritol tetranitrate (PETN). These are substances that have

in the immediate past been specifically not controlled by Note 7 of the ML 8; they are also not listed in the MTCR. The NDUL 6.4 lists the following substances in common with the IML and USML: HMX, HNS, RDX, and TATB.

Entries in the control lists also do not always cover the same qualities or grades of a particular substance. In the following table separate entries are provided for the each listed quality of a controlled substance, where different qualities are to be found in different control lists. However, the different qualities have been combined under their common substance name in the alphanumeric datasheets (Section IV).

Table 1. Controlled Substance Regulation Matrix

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
Aluminium	Note 1.a.1	§121.12.a.1		Spherical powder of particle size ≤60 micrometers; manufactured from material with an Al content of 99% by weight or greater.
Aluminium			4.a.4	Spherical powder with particles of uniform dia. of <500 micrometers and an aluminum content of 97% by weight or greater of Al
Aluminum Hydride	Not controlled	Not controlled	Not controlled	Not specified
Zirconium	Note 1.a.2 [sponge not listed]	§121.12.a.2 [sponge not listed]		Powders in particle sizes <60 micro-meters whether spherical, atomized, spheroidal, flaked, [sponge], or ground.
Zirconium			4. a.5	Particle sizes <500 micrometers, whether spherical, atomized, sphe-roidal, flaked, or ground consisting of 97% by weight or more of Zr
Lithium	Not controlled; but of interest	Not controlled; but of interest	Not controlled; but of interest	0.5 micrometer to 9/16 inch spherical powders and shapes

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
Lithium Hydride	Not controlled; but of interest	Not controlled; but of interest	Not controlled; but of interest	Not specified
Magnesium	Note 1.a.2	§121.12.a.2		Powders in particle sizes <60 micro-meters whether spherical, atomized, spheroidal, flaked, [sponge], or ground.
Magnesium			.a.5	Particle sizes <500 micrometers, whether spherical, atomized, spher-oidal, flaked, or ground consisting of 97% by weight or more of Mg
Beryllium	Note 1.a.2	§121.12.2		Powders in particle sizes <60 micro-meters whether spherical, atomized, spheroidal, flaked, [sponge], or ground.
Beryllium			4.a.5	Particle sizes <500 micrometers, whether spherical, atomized, spheroidal, flaked, or ground consisting of 97% by weight or more of Be
Beryllium Hydride	Not controlled; but of interest	Not controlled; but of interest	Not controlled; but of interest	Not specified
Iron powder produced by reduction of iron oxide with hydrogen	Note 1.a.2	§121.12.a.2		Powder with an average particle size of 3 micrometers or less produced by reduction of iron oxide with hydrogen
Encapsulated metals, composed of aluminum, magnesium, zirconium, or beryllium	Note 1.a.2	§121.12.a.3		Powders in particle sizes <60 micro-meters whether spherical, atomized, spheroidal, flaked, [sponge], or ground.

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
Alloys of zirconium, beryllium, boron, magnesium, or zinc			4.a.5	Particle sizes <500 micrometers, whether spherical, atomized, spheroidal, flaked, or ground consisting of 97% by weight or more of the alloys
Alloys of zirconium, boron, magnesium	Note 1.a.2	§121.12.a.2	4.a.5	Powders in particle sizes <60 micro-meters whether spherical, atomized, spheroidal, flaked, [sponge], or ground.
Boron	Note 1.a.2	§121.12.a.2		85% or higher purity; average particle size of ≤5 micrometers
Boron	Note 1.a.2	§121.12.a.2		Powders in particle sizes <60 micro-meters whether spherical, atomized, spheroidal, flaked, [sponge], or ground.
Boron			4.a.5	Particle sizes <500 micrometers, whether spherical, atomized, spheroidal, flaked, or ground consisting of 97% by weight or more of B
Boron Carbide	Note 1.a.2			85% or higher purity; average particle size of ≤5 micrometers
Zinc			4.a.5	Particle sizes <500 micrometers, whether spherical, atomized, spheroidal, flaked, or ground consisting of 97% by weight or more of Zn
Titanium	Not controlled; but of interest	Not controlled; but of interest	Not controlled; but of interest	1–3 micrometer powder; 99% purity

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
Perchlorates, chlorates and chromates composited with powdered metal	Note 1.a.3	§121.12.a.4	4.a.7	
Nitroguanidine	Note 1.a.4	§121.12.a.8		None specified; but particularly high-density, or spherical NQ (See Notes)
Carboranes	Note 1.a.6	§121.12.a.10	4.a.8	Not specified
Boron hydride(s)	Note 1.a.6	§121.12.a.10	4.a.8	Not specified
Diborane	Note 1.a.6	§121.12.a.10	4.a.8	Not specified
Decaborane	Note 1.a.6	§121.12.a.10	4.a.8	Not specified
Pentaborane	Note 1.a.6	§121.12.a.10	4.a.8	Not specified
Pentaborane derivatives	Note 1.a.6	§121.12.a.10	4.a.8	Not specified
Triethylborane	Note 1.a.6	§121.12.a.10	4.a.8	Not specified
Cyclotetramethy–lenetetranitramine	Note 1.a.7	§121.12.a.11	4.a.6	Not specified
Hexanitrostilbene	Note 1.a.8	§121.12.a.12		Not specified, but there are four principal grades based on particle size and known as HNS I, II, Superfine, and IV. It is the last two which are most critical for military use. (See Notes)
Diaminotrinitro-benzene	Note 1.a.9	§121.12.a.13		Not specified
Triaminotrinitro-benzene	Note 1.a.10	§121.12.a.14		Not specified
Triaminoguanidine nitrate	Note 1.a.11	§121.12.a.15		
Titanium subhydride of stoichiometry TiH 0.65-1.68	Note 1.a.12	§121.12.a.16		
Dinitroglycoluril	Note 1.a.13	§121.12.a.17		Not specified
Tetranitroglycoluril	Note 1.a.13	§121.12.a.17		Not specified

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
Tetranitrobenzo-triazolobenzo-triazole	Note 1.a.14	§121.12.a.18		Not specified
Diaminohexanitro-biphenyl	Note 1.a.15	§121.12.a.19		Not specified
Picrylaminodinitro-pyridine	Note 1a..16	§121.12.a.20		Not specified
Nonanitroterpheny lonanitroterphenyl	Not controlled; but of interest.			Not specified
5-nitro-2,4-dihydro-3H-1,2,4-triazol-3-one	Note 1.a.17	§121.12.a.21		Not specified
Hydrazine	Note 1.a.18	§121.12.a.22	4.a.1	In concentrations of 70% or more
Hydrazine nitrate	Note 1.a.18	§121.12.a.22		Not specified
Hydrazine perchlorate	Note 1 a.18	§121.12.a.22		Not specified
Unsymmetrical dimethyl hydrazine	Note 1.a.18	§121.12.a.22	4.a.2	Not specified
Monomethyl hydrazine	Note 1.a.18	§121.12.a.22	4.a.1	Not specified
Symmetrical dimethyl hydrazine	Note 1.a.18	§121.12.a.22		Not specified
Ammonium perchlorate	Note 1.a.19	§121.12.a.23	4.a.3	Not specified
Cyclotrimethylene-trinitramine	Note 1.a.20	§121.12.a.35	4.a.6	None specified; marketed in various grades based on particle size
Hydroxylammo-nium nitrate	Note 1.a.21	§121.12.a.36		Not specified
Hydroxylammo-nium perchlorate	Note 1.a.21	§121.12.a.36		Not specified
2-(5-cyanotetra-zolato)penta-amminecobalt(III) perchlorate	Note 1.a.22	§121.12.a.24		Not specified
cis-bis(5-nitrotetra-zolato)tetraammine cobalt(III) perchlorate	Note 1.a.23	§121.12.a.25		Not specified

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
7-amino-4,6-dinitrobenzo-furazane-1-oxide	Note 1.a.24	§121.12.a.26		Not specified
5,7-diamino-4,6-dinitrobenzo-furazane-1-oxide	Note 1.a.25	§121.12.a.27		Not specified
2,4,6-trinitro-2,4,6-triazacyclo-hexanone	Note 1.a.26	§121.12.a.28		Not specified
2,4,6,8-tetranitro-2,4,6,8-tetra-azabicyclo(3,3,0)-octanone-3	Note 1.a.27	§121.12.a.29		Not specified
1,1,3-trinitroazetidine	Note 1.a.28	§121.12.a.30		Not specified
1,4,5,8-tetranitro-1,4,5,8-tetraazadecalin	Note 1.a.29	§121.12.a.31		Not specified
Hexanitrohexa-azaisowurtzitane	Note 1.a.30	§121.12.a.32		Not specified
Hexanitrohexa-azaisowurtzitane clathrates	Note 1.a.30	§121.12.a.32		Not specified
Polynitrocubanes with more than four nitro groups	Note 1.a.31	§121.12.a.33		Not specified
Ammonium dinitramide	Note 1.a.32	§121.12.a.34		Not specified
Potassium dinitramide	Not controlled; but of interest	Not controlled; but of interest	Not controlled; but of interest	Not specified
bis (2,2,2-trinitroethyl-N-nitro)ethylene diamine	Not controlled; but of interest	Not controlled; but of interest	Not controlled; but of interest	Not specified
Oxalohydroxamic Acid	Not controlled; but of interest	Not controlled; but of interest	Not controlled; but of interest	Not specified
Diaminofurazan	Not controlled; but of interest			Not specified
Nitrocellulose	Specifically not controlled by Note 7.u	a. §121.14.h.1; Grades with N content >12.4% de-controlled; lower grades not controlled		Nitrogen content >12.2%

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
Ethane-1,1,1-tris(hydroxymethyl) trinitrate	Not controlled; but of interest. See TMETN below.	Not controlled; but of interest. See TMETN below.	4.e.4.ii	Not specified
Trimethylolethane trinitrate [see MTN above]			4.e.4.ii	Not specified
Triethylene glycol dinitrate	Specifically not controlled by Note 7.bb		4.e.4.iii	Not specified
Diethylene glycol dinitrate			4.e.4.iv	Not specified
Hydrogen peroxide of >85% concentration	Not listed; but conc.<85% specifically not controlled			>85% concentrations
Dinitrogen trioxide			4.a.9.ii	Not specified
Nitrogen dioxide		§121.16.4.a.9.1	See mixed nitrous oxide below	Not specified
Mixed nitrous oxide-nitrogen tetroxide	Not controlled, but of interest		4.a.9.ii	Not specified
Dinitrogen pentoxide			4.a.9.iii	Not specified
Enriched nitric acid (inhibited red fuming nitric acid)	Item 8.e	§121.12.f.1	4.a.9.iv	Not specified
Oxy fluoride		§121.12.f.2	See compounds composed of fluorine, etc. below	Not specified
Oxygen difluoride	Item 8.e	Not explicitly controlled, but controlled by the generality of oxyfluoride		Not specified
Compounds composed of fluorine and any of the following: other halogens, oxygen, or nitrogen	Note 1.a.5 [Note 7 excepts chlorine trifluoride]	§121.12.a.9 [with the exception of chlorine trifluoride]	See oxy fluoride above	Not specified

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
Compounds composed of fluorine and one or more of other halogens, oxygen, or nitrogen		§121.16.4.9.3	4.a.9.v	Not specified
Glycidylazide polymer	Note 2.a	§121.12.b.1	4.b.3	Not specified
Glycidylazide polymer derivatives	Note 2.a	§121.12.b.1		Not specified
Polycyanodifluoro-aminoethylene-oxide	Note 2.b	§121.12.b.2		
Butanetriol trinitrate	Note 2.c	§121.12.b.3		Not specified (but it is the acid-free grade that is required)
Bis-2-fluoro-2,2-dinitroethylformal	Note 2.d	§121.12.b.4		Not specified
Butadiene-nitrileoxide	Note 2.e			Not specified
Dicyclopentadienyl iron derivatives	Note 2.f	§121.12.b.5		Not specified
2,2-bis(ethylferrocenyl) propane	Note 2.f	§121.12.b.5	4.e.3.i	Not specified
Ferrocene carboxylic acids	Not controlled specifically, but controlled by the generalities of Note 2.f	Not controlled specifically, but controlled by the generalities of §121.12 b(5)		Not specified
Diferrocenylethane	Not controlled specifically, but controlled by the generalities of Note 2.f.	Not controlled specifically, but controlled by the generalities of §121.12 b(5)		Not specified
Butacene	Not controlled specifically, but controlled by the generalities of Note 2.f.	Not controlled specifically, but controlled by the generalities of §121.12 b(5)	4.e.3.iii	Not specified
N-butyl-ferrocene	Note 2.f	§121.12b.5	4.e.3.ii	Not specified
Bis(2,2-dinitropropyl) formal	Note 2.g	§121.12.b.6		Not specified
Bis(2,2-dinitropropyl) acetal	Note 2.g	§121.12.b.6		Not specified

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
Energetic monomers, plasticizers, and polymers containing nitro, azido, nitrate, nitraza, or difluoroamino groups	Note 2.i	§121.12.7		Not specified
3-nitraza-1,5-pentane diisocyanate	Note 2.h			Not specified
1,2,3-tris[1,2 bis(difluoroamino) ethoxy] propane	Note 2.j	§121.12.b.8		Not specified
Bis(azidomethyl)-oxetane	Note 2.k	§121.12.b.9		Not specified
Nitratomethyl-methyloxetane	Note 2.l	§121.12.b.10		Not specified
Azidomethyl-methyloxetane	Note 2.m	§121.12.b.10		Not specified
Polynitroortho-carbonates	Note 2.n			Not specified
Tetraethylenepentamine-acrylonitrile	Note 2.o	§121.12.b.11	4.e.1.iv [incorrectly written in text]	Not specified
Cyanoethylated polyamine salts	Note 2.o	§121.12.b.11		Not specified
Tetraethylene-pentamine acrylonitrile glycidol	Note 2.p	§121.12.b.12	4.e.1.iii	Not specified
Salts of tetraethylenepentamine acrylonitrile glycidol	Note 2.p	§121.12.b.12		Not specified
2-methyl aziridine amide with isophthalic backbone structure	Note 2.q	§121.12.b.13	4.e.1.v	Not specified
2-ethyl aziridine amide with trimesic backbone structure	Note 2.q	§121.12.b.13	4.e.1.v	Not specified
2-ethyl aziridine amide with isocyanuric backbone structure	Note 2.q	§121.12.b.13	4.e.1.v	Not specified

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
2-ethyl aziridine amide with trimethyladipic backbone structures	Note 2.q	§121.12.b.13	4.e.1.v	Not specified
bis(2-hydroxy-ethyl)glycolamide	Note 2.dd	§121.12b.24		Not specified
Lead 2-ethylhexoate	Not listed; but of interest	Not listed - previously listed		Not specified
Basic copper salicylate	Note 2.r	§121.12.b.14		Not specified
Lead salicylate	Note 2.r	§121.12.b.14		Not specified
Lead beta resorcylate	Note 2.s	§121.12.b.15		Not specified
Lead stannate	Note 2.t	§121.12.b.16		Not specified
Lead maleate	Note 2.t	§121.12.b.16		Not specified
Lead citrate	Note 2.t	§121.12.b.16		Not specified
Tris-1-(2-methyl) aziridinyl phosphine oxide	Note 2.u	§121.12.17	4.e.1.i	Not specified
Tris-1-(2-methyl) aziridinyl phosphine oxide derivatives	Note 2.u	§121.12.b.17		Not specified
Bis(2-methyl-aziridinyl) 2-(2-hydroxypropan oxy)propylamino–phosphine oxide	Note 2.u	§121.12.b.17		Not specified
Bis(2-methyl aziridinyl) methyl-amino phosphine oxide	Note 2.v	§121.12.b.17 [a derivative]		Not specified
Neopentyl (diallyl) oxy, tri(dioctyl) phosphato titanate	Note 2.w.1	§121.12.b.18.i		Contains 5% Isopropyl alcohol (CAS 67-63-0)/ Isooctyl alcohol (26952-21-6)

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
Titanium IV [(2-propenolato-1 methyl, n-propano-latomethyl] butanolato-1, tris(dioctyl)pyro-phosphato	Note 2.w.2	§121.12.b.18.ii		Not specified
Titanium IV[(2-propenolato-1) methyl, N-propanol-atomethyl] butanolato-1, tris(dioctyl)-phosphato	Note 2.w.3	§121.12.b.18.iii		Not specified
poly-[2,2,3,3,4,4-hexafluoro pentane-1,5-diol formal]	Note 2.x	§121.12.b.19		Not specified
poly-[2,4,4,5,5, 6,6-heptafluoro-2-trifluoromethyl-3-oxaheptane-1,7-diol formal]	Note 2.y	§121.12.b.20		Not specified
Polyglycidyl nitrate	Note 2.z	§121.12.b.21		Not specified
Carboxyl terminated polybutadiene			4.b.1	MILSPEC: Nonfunc-tional Type I (low acid); Type II (high acid)
Hydroxyl terminated polybutadiene	Note 2.aa	§121.12.a.38	4.b.2	With a hydroxyl functionality of 2.28, a hydroxyl value of 0.77 meq/g and a viscosity at 30 °C of <47 poise. MTCR controls without qualification
Polybutadiene-acrylic acid			4.b.4	Not specified
Polybutadiene acrylic acid-acrylonitrile			4.b.5	Not specified
Lead-copper chelates of beta-resorcylate/-salicylate	Note 2.bb	§121.12.b.22		MILSPEC MIS-30864; MILSPEC MIL-B-85735

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
Triphenyl bismuth	Note 2.cc	§121.12.b.23	4.e.2.i	Not specified
N-methyl-4-nitroaniline	Note 2.ff	§121.12.d.1	4.e.5.ii	Not specified
Amine-based antioxidants		Controlled by §121.12.d.2, as Protech		Not specified
Phenol-based antioxidants		Controlled by §121.12.d.2, as Protech		Not specified
Iron oxide	Note 2.ee	§121.12.b.25		Fine powder with a specific surface greater than 250 sq. meters per gram and an average particle size of 0.003 micrometers or less
Military fuel thickeners—compounds (e.g., octal) or mixtures of compounds (e.g., napalm) specifically formulated to produce materials which when added to petroleum products provide a gel-type incendiary for use in bombs, projectiles, flame throwers.	Note 4			Not specified
Aluminum octadecanoate	Note 4; but not named except as Octal			Not specified
M1 thickener	Note 4			Not specified
M2 thickener	Note 4			Not specified
M4 thickener	Note 4; [mislabeled M3]			Not specified
Guanidine nitrate	Note 5.a; or transfer to IL.1.C.11			Not specified
1,2,4 trihydroxybutane	Note 5.a; or transfer to IL.1.C.11	§121.12.c.1		Not specified

SUBSTANCE or COMPOSITION	CONTROL BY NF ML 8	CONTROL BY USML CAT V	CONTROL BY MTCR CAT II	QUALITY CONTROLLED
1,3,5-trichlorobenzene	Note 5.a; or transfer to IL.1.C.11	§121.12.c.2		Not specified
Bis(chloromethyl-oxetane)	Note 5; §121.12.	§121.12.c.3		Not specified
Alcohol-functionalized polyepichloro-hydrin; diol and triol	Note 5.e	§121.12.c.4		<10,000 molecular weight
Propyleneimine	Note 5.f	§121.12.c.5		Not specified
1,3,5,7 tetraacetyl-1,3,5,7-tetraaza-cyclooctane	Note 5.g	§121.12.c.6		Not specified
Dinitroazetidine-tertiary-butyl salt	Note 5.h	§121.12.c.7		Not specified
Hexabenzylhexa-azaisowurtzitane	Note 5.i	§121.12.c.8		Not specified
Tetraacetyldi-benzylhexaazaiso-wurtzitane	Note 5.j	§121.12.c.9		Not specified
1,4,5,8-tetraazadecalin	Note 5.k	§121.12.c.10		Not specified
Nitroform	Not controlled; but a key precursor for advanced military explosive ingredients	Not controlled; but a key precursor for advanced military explosive ingredients	Not controlled; but a key precursor for advanced military explosive ingredients	Not specified
Alkyl-propyl trimethylol propane	Not controlled; but of interest; listed in 1992 MCTL			Not specified
Meta-nitroaniline	None; listed in 1992 MCTL			Not specified
Nickel-aluminum active metals	Not controlled; but of interest	Not controlled; but of interest	Not controlled; but of interest	Pyrophoric surfaces on metal or polymeric foils

III. DATA SHEETS

A. GENERAL

This section of the document contains (1) the data sheet template, intended to facilitate recording of further notes and the periodic updating of entries as new information becomes available and, (2) the data sheets themselves. Appendix A is an index of the data sheets. Appendix B is an index of the preferred substance names. Appendix C is an index of synonyms for substances which are listed in the data sheets by their preferred names.

B. THE DATA SHEET TEMPLATE

1. Substance or Composition: The preferred chemical name of the substance. **2. CAS Registry No.:** Chemical Abstract Service registry number. **4. Acronym(s) or Trade Designation(s):** Short name commonly used for the substance in government or inmdustry.	**3. Molecular Structure:** The molecular structure of the substance, if a complex molecule.

5. Synonyms:
Other chemical names for the substance to be found in government documents.

6. Chemical Composition:
The elemental chemical composition of the substance.

7. Control Status:
The export control reference(s) that list the substance.

8. Quality:
The quality of the substance controlled, if given in the control list(s). These may differ from list to list for the same substance.

9. Precursors:
Listed or unlisted substances that are required for the production of the substance. If a precursor is listed, a separate data sheet for the substance is provided.

10. Precursor Quality:
Any quality of a precursor that is defined or implied by a control list.

11. Production Process:
Chemical process used to manufacture the product from precursors.

12. Production Equipment:
Listed equipment that is required for the particular process.

13. U.S. Producers:
Known U.S. producers of the substance for defense application, and a point of contact for further information on production parameters and customers.

14. Production Capacity: The actual or potential production capacities of the listed producer(s).	**15. Cost:** The approximate cost of the substance at the listed production rates.

16. Shipping Pack & Label:
The UN Hazard Classification label or other packaging of the substance that may help identify it in storage or stowage.

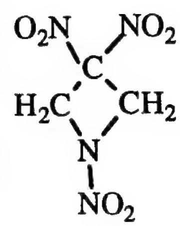
17.	**Color & Form:** The color and form (compressed gas, solid, or liquid) of the substance as normally encountered during shipping and handling.
18.	**Foreign Producers:** Known foreign producers of the substance.
19.	**Foreign Capacities:** Production capacities, if known, of foreign producers.
20.	**Military Uses:** The military applications of the material.
21.	**Civil Uses:** Civil applications of the substance, if they consume a significant proportion of a producer's capacity.
22.	**Notes:** Comments on, or amplifications of, the entries in other cells of the data sheets. Or a summary of the control history of the substance, particularly where this has evolved or where other changing factors suggest that a review of the status of the substance may be desirable.
23.	**References/MILSPECS:** Reference to sources cited in foregoing cells.

C. DATA SHEETS FOR LISTED ENERGETIC MATERIALS

1. Substance or Composition:
1,1,3-trinitroazetidine

2. CAS Registry No.:
97645-24-4

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
TNAZ

5. Synonyms:
1,1,3-trinitro-3-azacyclobutane;
1,1-dinitro-3-nitrazacyclobutane

6. Chemical Composition:
$C_3H_4N_4O_6$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

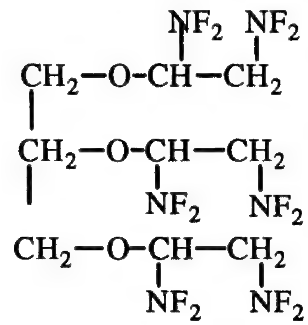
9. Precursors:
Dinitroazetidine-tertiary-butyl salt

10. Precursor Quality:
Not specified

11. Production Process:
Confidential

12. Production Equipment:
Proprietary

13. U.S. Producers: US Army, ARDEC, Picatinny NJ 07806-5000 Tel:(201) 724 5473; FAX: (201) 724-5713; DCN 880-5473; Contact: Dr. Sury Iyer. or, Aerojet Div., GENCORP, Sacramento CA Tel: (916) 355-6967. Thomas Archibald.	
14. Production Capacity: Pilot plant quantities only at Sacramento	**15. Cost:** >$50.00 per lb.
16. Shipping Pack & Label: UN Class 1.1 explosive	
17. Color & Form: White/colorless crystals	
18. Foreign Producers: None	
19. Foreign Capacities:	
20. Military Uses: Ingredient of developmental, low sensitivity, high energy high explosive charges	
21. Civil Uses: None	
22. Notes: TNAZ is about 3 percent more powerful than HMX, but with a lower sensitivity to impact; moreover it melts at about 101° C, and being steam-castable is immediately adoptable for use in existing munitions loading facilities. Its production requires the precursor, dinitroazetidine-tertiary-butyl salt or 1-t-butyl-3,3-dinitroazetidine; the laboratory-scale process developed at Fluorochem is now being scaled up by the U.S. Army at ARDEC, Dover, NJ, in readiness for the application of TNAZ in candidate fills for powerful, low-vulnerability munitions that will be unique to the U.S. Army and Air Force. United States is the only country known to be applying the substances for the development of new formulations, and to be producing them in pilot plant quantities. The explosive was originally synthesized (lab. process only) by Fluorochem, 680 S. Ayon Ave., Azusa CA 91702. Tel: (818) 334-6714.	
23. References/MILSPECS:	

1. Substance or Composition: 1,2,3-tris[1,2 bis(difluoroamino) ethoxy] propane **2. CAS Registry No.:** 53159-39-0 **4. Acronym(s) or Trade Designation(s):** TVOPA	**3. Molecular Structure:** 

5. Synonyms:
tris vinoxy propane adduct

6. Chemical Composition:
$C_9H_{14}N_6O_3F_{12}$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
NF_2

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Unknown

14. Production Capacity:
Unknown

15. Cost:
Not available

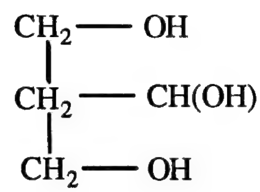
16. Shipping Pack & Label:
Not specified

17.	**Color & Form:** Unknown
18.	**Foreign Producers:** Unknown
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Plasticizer for acrylate-acrylic acid co-polymers used as binders for missile propellants
21.	**Civil Uses:** None
22.	**Notes:** Several years ago an explosion destroyed the Soviet plant for the manufacture of NF_2, a precursor for TVOPA. The FSU may continue to lack production capability for NF_2 and its derivatives. TVOPA has been in use by the U.S. for over 30 years, but its high cost has tended to encourage the use of replacements such as BTTN.
23.	**References/MILSPECS:**

1. Substance or Composition:
1,2,4 trihydroxybutane

2. CAS Registry No.:

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):

5. Synonyms:
1,2,4-butanetriol;
Methyl glycerol
Trihydroxybutane

6. Chemical Composition:
$C_4H_{10}O_3$

7. Control Status:
Controlled by ML-8 Note 5; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Unknown

14. Production Capacity:
Not available

15. Cost:
Not available

16. Shipping Pack & Label:

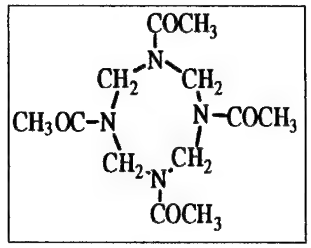
17. Color & Form:
Viscous liquid

18.	**Foreign Producers:** Widely available
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** The precursor for the manufacture of BTTN.
21.	**Civil Uses:**
22.	**Notes:** A widely available substance, its embargo is probably justified only to the extent that its quality affects the ability to produce acid-free BTTN.
23.	**References/MILSPECS:**

1. Substance or Composition:
1,3,5,7 tetraacetyl-1,3,5,7-tetraaza-cyclooctane

2. CAS Registry No.:
41378-98-7

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
TAT

5. Synonyms:
1,3,5,7-tetraacetyl-1,3,5,7-octahydroazocine

6. Chemical Composition:
$C_{12}H_{20}N_4O_4$

7. Control Status:
Controlled by ML-8 Note 5; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Gardee process

12. Production Equipment:
Not specified; drums probable

13. U.S. Producers:
U.S. Army ARDEC

14. Production Capacity:
Limited

15. Cost:
Not available

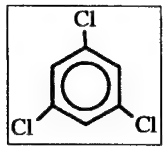
16. Shipping Pack & Label:
Not specified

17.	**Color & Form:** White crystals
18.	**Foreign Producers:** None, except perhaps France & China for experimental purpose.
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Precursor for the manufacture of HMX by the TAT or GARDEC process
21.	**Civil Uses:** None
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition:
1,3,5-trichlorobenzene

2. CAS Registry No.:
108-70-3

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):

5. Synonyms:

6. Chemical Composition:
C_6H/Cl_3

7. Control Status:
Controlled by ML-8 Note 5; USML CAT V §121.12

8. Quality:
Not specified

9 Precursors:
None

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
None

14. Production Capacity:
Not available

15. Cost:
Not available

16. Shipping Pack & Label:
Drums

17. Color & Form:
Long needles

18. Foreign Producers:
Japan ? Former Soviet bloc ?

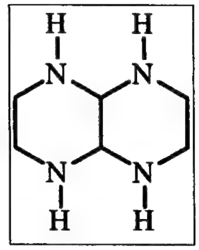
19. Foreign Capacities:
Unknown

20.	**Military Uses:** A precursor for the manufacture of TATB
21.	**Civil Uses:** A precursor for the manufacture of an insecticide
22.	**Notes:** A precursor for the manufacture of TATB, this is a toxic substance produced originally in GE and used for the synthesis of an insecticide. The insecticide is now widely-prohibited, and it was reported in 1991 that Japan had become the sole supplier of the substance outside the former Soviet bloc countries.
23.	**References/MILSPECS:**

1. Substance or Composition:
1,4,5,8-tetraazadecalin

2. CAS Registry No.:
5409-42-7

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):

5. Synonyms:
1,4,5,8-tetraaza-bicyclo[4,4,0] decane

6. Chemical Composition:
$C_6H_{14}N_4$

7. Control Status:
Controlled by ML-8 Note 5; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Not specified

12. Production Equipment:
Not specified

13. U.S. Producers:
None

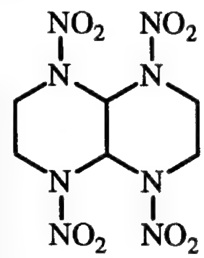
14. Production Capacity:
None

15. Cost:
Not available

16. Shipping Pack & Label:
Not specified

17. Color & Form:
Unknown

18. Foreign Producers: France	
19. Foreign Capacities: Unknown	
20. Military Uses: Precursor for TNAD	
21. Civil Uses: None	
22. Notes:	
23. References/MILSPECS:	

1. Substance or Composition: 1,4,5,8-tetranitro-1,4,5,8-tetraazadecalin	**3. Molecular Structure:** 
2. CAS Registry No.: 135877-16-6	
4. Acronym(s) or Trade Designation(s): TNAD	

5. Synonyms:
1,4,5,8-tetranitrazadecalin;
1,4,5,8-tetranitro-1,4,5,8-tetrazabicyclo [4,4,0]decane;
1,4,5,8-tetranitrazabicylo[4,4,0]decane

6. Chemical Composition:
$C_6H_{10}N_8O_8$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
1,4,5,8-tetraazadecalin

10. Precursor Quality:
Not specified

11. Production Process:
Nitrosation of 1,4,5,8-tetraazadecalin to the tetranitroso compound, which is then nitrolyzed to TNAD.

12. Production Equipment:
Nitration plant

13. U.S. Producers:
None

14. Production Capacity: None	**15. Cost:** Not available

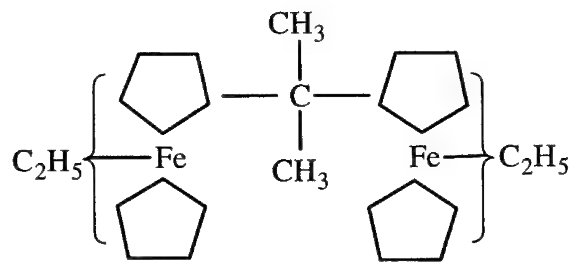
16. Shipping Pack & Label:
Hazard Class 1.1 explosive

17.	**Color & Form:** White crystals
18.	**Foreign Producers:** SNPE, France
19.	**Foreign Capacities:** Pilot plant only
20.	**Military Uses:** Ingredient of developmental, low sensitivity, moderate energy high explosive charges
21.	**Civil Uses:** None
22.	**Notes:** TNAD is quite energetic, less sensitive than RDX, and has a high melting point of about 233° C. France is the only country known to be using it for the development of new formulations, and to be producing it in pilot plant quantities.
23.	**References/MILSPECS:**

1. Substance or Composition:
2,2-bis(ethylferrocenyl) propane

2. CAS Registry No.:
37206-42-1

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
Catocene™

5. Synonyms:

6. Chemical Composition:
$C_{27}H_{32}Fe_2$

7. Control Status:
Controlled by ML-8 Note 2.f; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9. Precursors:
Ferrocene; acetyl ferrocene; and/or ethylferrocene

10. Precursor Quality:
Not specified

11. Production Process:
15 step batch process (See notes)

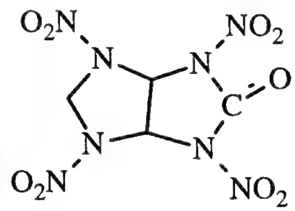
12. Production Equipment:
Proprietary distillation and purification systems, specially designed and built by Syntex. Not specifically listed in control lists.

13. U.S. Producers:
Syntex Agribusiness Inc.,
Nutrition & Chemical Division
P.O. Box 1246
Springfield MO 65801
Tel: (417) 866-7291 X3333
FAX: (417) 868-3353
Contact: Mr. Larry Wakefield, Materials Manager

14. Production Capacity:
Up to 1000 kg/mo.

15. Cost:
579 /kg.

16.	**Shipping Pack & Label:** No UN Hazard Class; shipped in 5 gal. metal drums.
17.	**Color & Form:** Straw colored, oily viscous liquid.
18.	**Foreign Producers:** PLUTO, Germany
19.	**Foreign Capacities:**
20.	**Military Uses:** Burn rate modifier and smoke reducer for solid propellants, used in Standard and other missiles.
21.	**Civil Uses:** None
22.	**Notes:** At present the U.S. production plant is idle, and has been for three years, although there is no current intent to dismantle the capability. There is no interest to pursue contracts in the face of foreign competition. In the event of a national emergency the company is prepared to reconsider. Catocene™ is presumably imported to meet the needs of U.S. missile propellant manufacturers. It is possible that foreign capabilities are based on a continuous process that yields a cheaper product. Problems with the safety of catocene-containing formulations may limit their future use, and place greater emphasis on other metallo-organic derivatives. Among other alkyl derivatives of concern are ethyl ferrocenes, and 1,1 dimethyl ferrocene, and their condensation products with aldehydes and ketones. Although the catocene name is trademarked, its retention in control lists has been recommended, as it is practically never known by any other name. It probably would not be recognized even by people in the field if its chemical name stood alone; and it has derivations of its own, such as "Hi-Cat-6," an early U.S. propellant ingredient.
23.	**References/MILSPECS:**

1. Substance or Composition: 2,4,6,8-tetranitro-2,4,6,8-tetraazabicyclo(3,3,0)-octanone-3	**3. Molecular Structure:** 
2. CAS Registry No.: 130256-72-3	
4. Acronym(s) or Trade Designation(s): K-55; ketobicyclo HMX	

5. Synonyms:
Tetranitrosemiglycoluril;
2,4,6,8-tetranitrotetraazabicyclo(3,3,0)octan-3-one

6. Chemical Composition:
$C_4H_4N_8O_9$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Not specified

12. Production Equipment:
Not specified

13. U.S. Producers:
LLNL, Thiokol Corp., and Ensign Bickford.

14. Production Capacity:
Pilot plant capability only

15. Cost:
Not available

16. Shipping Pack & Label:
Class 1.1 high explosive

17. Color & Form:
White crystals

18. Foreign Producers:
None known

19. Foreign Capacities:

20. Military Uses:
High explosive munitions fill.

21. Civil Uses:
None

22. Notes:
The substance is an advance on HMX technology and is under consideration for conventional munitions and space systems. Its existence was predicted in 1986 at an ADPA meeting attended by representatives from foreign countries, and in earlier internal U.S. Navy reports. Subsequently, an unpublished presentation in New Orleans in 1988 presented details of a successful approach to the synthesis of K-55. The audience included representatives from France, UK, Netherlands, Norway, GE, Italy, Spain, Canada, and Japan among the NATO countries; other countries represented included CH, Sweden, Brazil, Israel, Finland, Switzerland, Egypt, and Yugoslavia.

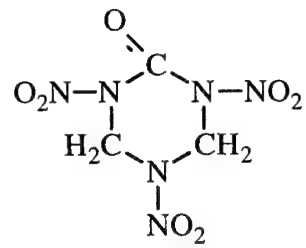
CH described the synthesis in the open literature and gave performance values, reporting work which they claimed to have initiated in 1967. They expressed interest in the U.S. approach because they had found the synthesis of bicyclic HMX without the Keto modification to be too laborious to be practical. The favorable properties of K-55 have been reported to include its superior hydrolytic stability in comparison with TNGU. Pilot plant facilities for the production of K-55 were under development in 1990 in the U.S.; no other country is known to have developed such facilities.

23. References/MILSPECS:

1. Substance or Composition:
2,4,6-trinitro-2,4,6-triaza-cyclohexanone

2. CAS Registry No.:
115029-35-1

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
K-6;
Keto-RDX

5. Synonyms:
2,4,6-trinitrazacyclohexanone;
2-oxo-1,3,5-trinitro-1,3,5-triazacyclohexane;
2-oxo-1,3,5-trinitrohexahydrotriazine;
1,3,5-trinitrotriazone

6. Chemical Composition:
$C_3H_4N_6O_7$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
2-oxo-5-*tert*-butyl-1,3,5-triazacyclohexane (or 5-*tert*-butyltriazone, TBT);
acetic anhydride;
fuming nitric acid (or H_2SO_4/HNO_3)

10. Precursor Quality:
>90% HNO_3 required for high yields

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Synthesized only at LLNL; pilot plant under development.

14. Production Capacity:
Limited

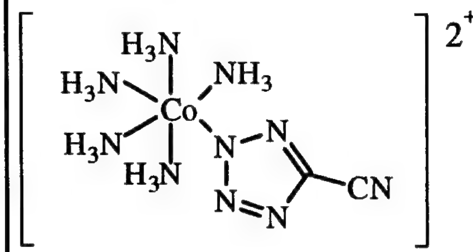
15. Cost:
Not available

16.	**Shipping Pack & Label:** UN Hazard, Class 1.1 Explosive
17.	**Color & Form:** White, crystalline powder
18.	**Foreign Producers:** China?
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Experimental high explosive fill
21.	**Civil Uses:** None
22.	**Notes:** This substance is an advances on RDX technology and under consideration for application in conventional munitions and space systems. K-6 is the analogue of K-55 (qv), and their existence was predicted in 1986 at an ADPA meeting attended by representatives from foreign countries, and in earlier internal U.S. Navy reports and presentations at LLNL. The stability of K-6 for military use may be open to question. CH described the synthesis of the compound in the open literature and gave performance values, reporting work which they claimed to have initiated in 1967. Pilot plant facilities for the production of K-6 are under development in the U.S.; no other country is known to have developed such facilities.
23.	**References/MILSPECS:** a. R. Mitchel, P. F. Pagoria, C. L. Coon, et al, *Propellants, Explosives, Pyro.*, 19, 232-239 (1994).

1. Substance or Composition:
2-(5-cyanotetrazolato)penta amminecobalt(III) perchlorate

2. CAS Registry No.:
70247-32-4

3. Molecular Structure:



$2ClO_4^-$

4. Acronym(s) or Trade Designation(s):
CP

5. Synonyms:
Pentaammine(5-cyano-2H-tetrazolato-N^2)cobalt(III)perchlorate

6. Chemical Composition:
$(C_2H_{30}N_{20}O_8)Cl_2Co_2$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
CPCN = pentamiminecarbonatecobalt(III) nitrate

10. Precursor Quality:
Not specified

11. Production Process:
Requires cyanogen, toxic substance, for its preparation.

12. Production Equipment:
Proprietary

13. U.S. Producers:
Pacific Scientific Inc.,
Energy Dynamics Div.
7073 West Willis Drive, Box 5002
Chandler AZ 85226-5111
Contact: Mr John Fronabarger
Tel: (602) 796-1100

14. Production Capacity:
Kilogram lots

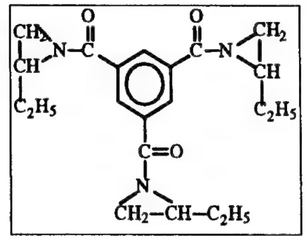
15. Cost:
About \$50.00/gram (\$22,800/lb)

16.	**Shipping Pack & Label:** UN Hazard Class 1.1 explosive.
17.	**Color & Form:** Golden orange crystals; the smaller the crystals the more yellow in appearance
18.	**Foreign Producers:** China; FSU? (See notes)
19.	**Foreign Capacities:** Limited, if any.
20.	**Military Uses:** Detonator explosive for nuclear warheads and missiles.
21.	**Civil Uses:** Use in oil well stimulators requiring lifetimes of 200 hr @ up to 340°F
22.	**Notes:** CP is in the USML V and ML 8 because of its potential for nuclear weapons and ICBM applications. CP has received extensive attention because of its stability and it is sufficiently powerful and easily detonated that it permits designers to get away from lead azide and PETN combinations for the initiation of HMX by either laser or hot-wire techniques. It is used only in very small quantities in detonators. The method of preparing CP and its properties have been described in the open literature; both China and the FSU have published papers on its synthesis but are not known to produce it in quantity; however, see the discussion below for a possible FSU/CH alternative, ZOX. While CP (and BNCP) are only known to be produced in the U.S., CH and the FSU may be using formulations based on bis(2,2,2-trinitroethyl-N-nitro)ethylene diamine (or ZOX). This was first synthesized by the FSU in 1952 by Avansov and has undergone extensive development in CH since it was prepared there, at least as early as 1964 . It has apparently been neither exploited nor even prepared in any NATO country.
23.	**References/MILSPECS:**

1. Substance or Composition:
2-ethyl aziridine amide with isocyanuric backbone structure

2. CAS Registry No.:
More info. needed

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
TEAT, or HX-874

5. Synonyms:
2,4,6-tris(N-ethylethyleneimine)-1,3,5-triazine

6. Chemical Composition:
$C_{21}H_{30}O_3N_3$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

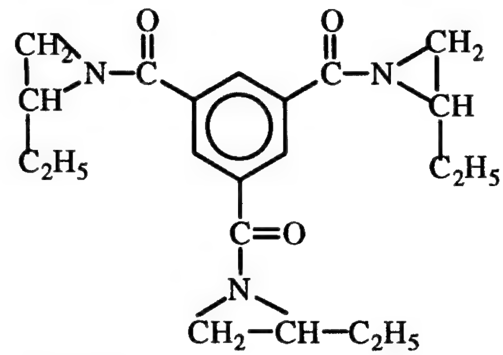
13. U.S. Producers:
3M Company, Specialty Chemicals Div.,
3M Center, 236-2A-01,
St. Paul MN 55144-1000.
Tel: 612 458-1392;
FAX: (612) 458-1383.
Dr. Anthony P. Manzara

14. Production Capacity: > 20 lb/year	**15. Cost:** Not available
16. Shipping Pack & Label: One or eight lb. units. Storage at 0°(-18°C) recommended.	
17. Color & Form: Solid (MP 45°C)	
18. Foreign Producers: None	
19. Foreign Capacities: Not available	
20. Military Uses: A bonding agent for ammonium perchlorate in energetic compositions, an extender or cross-linker for carboxyl pre polymers, and an adhesion promoter in solid rocket and high explosive munition interfaces.	
21. Civil Uses: None.	
22. Notes: TEAT cannot be shipped by air because of its toxicity. Its only known use, at a level of about 20 lb/year, is by Aerojet for a tactical missile program.	
23. References/MILSPECS:	

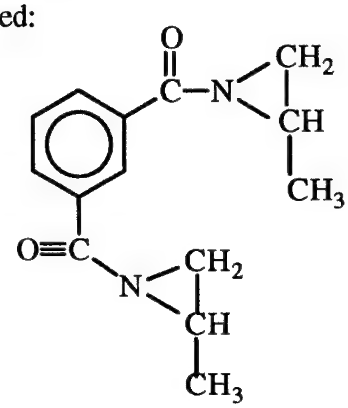
1. Substance or Composition:
2-ethyl aziridine amide with trimesic backbone structure

2. CAS Registry No.:
7722-73-8

3. Molecular Structure:



Or related:



4. Acronym(s) or Trade Designation(s):
BITA, or HX-868 (HX 876 when as a 40% solution version)

5. Synonyms:
Butylene imine trimesamide;
Trimesoyl-1(2-ethyl)aziridine;
Trimesoyl-tris(2-ethylethyleneimide)

6. Chemical Composition:
$C_{21}H_{30}O_3N_3$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9 Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: 3M Company, Specialty Chemicals Div., 3M Center, 236-2A-01, St. Paul MN 55144-1000. Tel: 612 458-1392; FAX: (612) 458-1383. Dr. Anthony P. Manzara	
14. Production Capacity: > 50 lb/year	**15. Cost:** Not available
16. Shipping Pack & Label: One or eight lb. units. Storage at 0°(-18°C) recommended, which may solidify otherwise normally liquid product.	
17. Color & Form: Liquid or solid (MP <60°C); may be in a 40% by weight benzene solution for easier shipping, handling, and storage.	
18. Foreign Producers: None	
19. Foreign Capacities: None	
20. Military Uses: A bonding agent for ammonium perchlorate in energetic compositions, an extender or cross-linker for carboxyl prepolymers, and an adhesion promoter in solid rocket and high explosive munition interfaces.	
21. Civil Uses: Unknown	
22. Notes: HX 868 is a CTPB cross-linking agent used in Minuteman and for HTPB liner adhesion. It is also known as BITA (butylene imine trimesamide). It is sold under OMC license to Bayern Chemie (GE) and to SNIA (Italy).	
23. References/MILSPECS:	

1. Substance or Composition: 2-ethyl aziridine amide with trimethyladipic backbone structures	**3. Molecular Structure:** Unknown
2. CAS Registry No.: More info. needed	
4. Acronym(s) or Trade Designation(s): HX 877; or HX 873 when in a 40% benzene solution version.	
5. Synonyms:	
6. Chemical Composition: Unknown	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12; MTCR	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: 3M Company, Specialty Chemicals Div., 3M Center, 236-2A-01, St. Paul MN 55144-1000. Tel: 612 458-1392; FAX: (612) 458-1383. Dr. Anthony P. Manzara	
14. Production Capacity: > 50 lb/year	**15. Cost:** Not available
16. Shipping Pack & Label: One or eight lb. units. Storage at 0°(-18°C) recommended, which may solidify otherwise normally liquid product.	

17.	**Color & Form:** Liquid; may be in a 40% by weight benzene solution for easier shipping, handling, and storage.
18.	**Foreign Producers:** None
19.	**Foreign Capacities:** Not applicable
20.	**Military Uses:** A bonding agent for ammonium perchlorate in energetic compositions, an extender or cross-linker for carboxyl pre polymers, and an adhesion promoter in solid rocket and high explosive munition interfaces.
21.	**Civil Uses:** None
22.	**Notes:** HX 877 is used by Aerojet in Standard missiles and by Thiokol as a chain extende. t may be used in the ALS system. It has been sold under OMC license to SNIA (Italy). There may have been instances in which bonding agents were illegally re-exported.
23.	**References/MILSPECS:**

1. Substance or Composition: 2-methyl aziridine amide with isophthalic backbone structure	**3. Molecular Structure:** Unknown
2. CAS Registry No.: 7652-64-4	
4. Acronym(s) or Trade Designation(s): HX-752 (or HX 875, as a 40% benzene solution)	
5. Synonyms: Isophthaloyl bis(2-methylethylineimide)	
6. Chemical Composition: Unknown	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12; MTCR	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: 3M Company, Specialty Chemicals Div., 3M Center, 236-2A-01, St. Paul MN 55144-1000. Tel: 612 458-1392; FAX: (612) 458-1383. Dr. Anthony P. Manzara	
14. Production Capacity: > 1000 lb/year	**15. Cost:** $85.00-100.00 per lb
16. Shipping Pack & Label: One or eight lb. units. Storage at 0°F(-18°C) recommended, which may solidify otherwise normally liquid product.	

17.	**Color & Form:** Liquid or solid (MP 35°C); may be in a 40% by weight benzene solution for easier shipping, handling, and storage(but see notes).
18.	**Foreign Producers:** See notes.
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** A bonding agent for ammonium perchlorate to HTPB in energetic compositions, an extender or cross-linker for carboxyl prepolymers, and an adhesion promoter in solid rocket and high explosive munition interfaces.
21.	**Civil Uses:** None
22.	**Notes:** Currently embargoed, although under license small amounts have been shipped to Thailand and one ton to Taiwan. In 1988, Korea bought 3500 lb and in 1987 Taiwan again received 750 lb. South Africa possibly received some. Requests from Pakistan, Brazil, and Argentina have been rejected; a request was received from Iran in March 1990. Several years ago it was reported that a Japanese source has sold an "HX-752" replica to Taiwan, but the quality was poor. Dissolving HX-752 in benzene permits non-refrigerated shipments; these were discontinued because of the toxicity of benzene.
23.	**References/MILSPECS:**

1. Substance or Composition: 3-nitraza-1,5-pentane diisocyanate **2. CAS Registry No.:** 7406-61-9 **4. Acronym(s) or Trade Designation(s):**None	**3. Molecular Structure:** NO_2 | $OCNCH_2CH_2NCH_2CH_2NCO$

5. Synonyms:
Unknown

6. Chemical Composition:
$C_6H_8N_4O_4$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Aerojet General Corp.

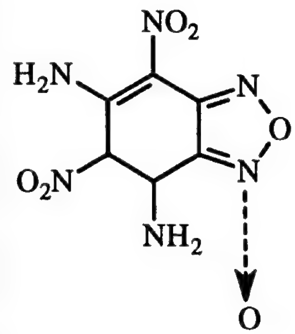
14. Production Capacity:	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 1.1 explosive

17. Color & Form:
Not available

18. Foreign Producers:
Exported to UK for Polaris applications. (see Notes)

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Energetic binder ingredient for missile solid propellant; used in Polaris system.
21.	**Civil Uses:** None
22.	**Notes:** Energetic isocyanates in general are, or would be, of interest in such contexts, if available outside the U.S. The FSU is believed to have introduced azidoisocyanates for similar applications.
23.	**References/MILSPECS:**

1. Substance or Composition: 5,7-diamino-4,6-dinitrobenzofurazane-1-oxide	**3. Molecular Structure:** 
2. CAS Registry No.: 117907-74-1	
4. Acronym(s) or Trade Designation(s): CL-14	

5.	**Synonyms:** Diaminodinitrobenzofuroxan; 5,7-diamino-4,6-dinitro-2,1,3-oxadiazole-1-oxide
6.	**Chemical Composition:** $C_6H_4N_6O_6$
7.	**Control Status:** Controlled by ML-8 Note 1a; USML CAT V §121.12
8.	**Quality:** Not specified
9.	**Precursors:** 5,7--4,6 dinitrobenzofuroxan; where halogeno = chloro or bromo.
10.	**Precursor Quality:** Not specified
11.	**Production Process:** Amination of precursor
12.	**Production Equipment:** Nitration plant

13. U.S. Producers:
Pilot plant under consideration by:
Ensign Bickford Industries Inc.
660 Hopmeadow St.,
P.O. Box 427, Simsbury CT 06070-0427
Tel: (203) 843-2225
FAX:(203) 843-2621
Contact: Mr. Pete McGuinness

14. Production Capacity:
Unknown

15. Cost:
Not available

16. Shipping Pack & Label:
Class I.1 D high explosive.

17. Color & Form:
White crystals

18. Foreign Producers:
Dept. of Chemical Engineering, Beijing Inst. of Technology, China.

19. Foreign Capacities:
Experimental quantities.

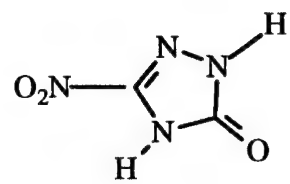
20. Military Uses:
Potential less sensitive high explosive fill for high-use munitions.

21. Civil Uses:

22. Notes:
This low sensitivity explosive with an energy between those of RDX and HMX has potential for use in low vulnerability munitions; it is more energetic and less sensitive than ADNBF. The substance has been synthesized in China (Ref. 1)

23. References/MILSPECS:

1. Boren Chen, Zhiyuan Liao. 21st. International Conference of ICT, Fraunhofer-Inst. für Chemische Technologie, Karlsruhe, Germany, 1990, pp. 58-1-4.

1. Substance or Composition: 5-nitro-2,4-dihydro-3H-1,2,4-triazol-3-one	**3. Molecular Structure:** 
2. CAS Registry No.: 932-64-9	
4. Acronym(s) or Trade Designation(s): NTO, OTN, or ONTA	

5. Synonyms:
3-nitro-1,2,4-triazol-5-one
1-hydro-3-1,2,4-triazole-5-onate

6. Chemical Composition:
$C_2H_2N_4O_3$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
None specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Ensign Bickford Industries Inc.
660 Hopmeadow St.,
P.O. Box 427, Simsbury CT 06070-0427
Tel: (203) 843-2225
FAX:(203) 843-2621
Contact: Mr. Pete McGuinness

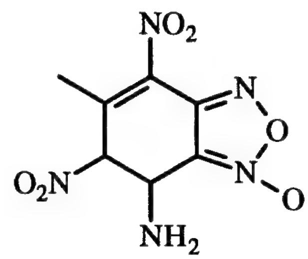
14. Production Capacity: 100,000 lb./year	**15. Cost:** $50-60/lb.

16.	**Shipping Pack & Label:** No UN Hazard Class assigned, but nominally a Class 1.1 explosive.
17.	**Color & Form:** White solid
18.	**Foreign Producers:** SNPE, France; China?
19.	**Foreign Capacities:** SNPE, France pilot plant is capable of producing 150 tonnes/year
20.	**Military Uses:** A less sensitive, high explosive fill for high-use munitions
21.	**Civil Uses:** None
22.	**Notes:** The first synthesis of NTO was described in 1906, but it was not exploited until recently. Because it does not detonate in small diameters its application as a high explosive will probably be limited to fills for bombs and large caliber projectiles. Its performance is close to that of RDX and is covered by control levels that have been listed since 1983; however, its resistance to impact is substantially greater than that of most standard explosives. Known as OTN in France, the substance was prepared independently in the laboratory there and in the U.S . A paper on French developments was present in CH in 1987. CH also has undertaken laboratory syntheses of the compound and may be seeking to produce it on a larger scale. Its synthesis was reported in Hungary and in the FSU without reference to its explosive properties, but there is no knowledge of any further developments in those countries. In the U.S. and France, the only countries in which confirmed process development is under way, most of the research has been conducted in Navy and DOE laboratories and by SNPE. The Navy sought contractors (e.g., Ensign Bickford) to produce 5000 pounds of the material for further evaluation. Although expected to be cheap to produce, NTO has acidic characteristics that may give compatibility problems when introduced into the metal parts of munitions. Its ultimate acceptability as a munitions fill has, therefore, yet to be demonstrated. It is possible that CH has developed at least a pilot plant production capability, as there is evidence that the properties of formulations based on NTO are being investigated. Alternatively, the substance may be obtained from France, the only other known producer outside the U.S.; however, its availability from indigenous sources is consistent with CH's claim to have independently synthesized the substance.
23.	**References/MILSPECS:**

1. Substance or Composition:
7-amino-4,6-dinitrobenzofurazane-1-oxide

2. CAS Registry No.:
97096-78-1

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
ADNBF

5. Synonyms:
Aminodinitrobenzofuroxan

6. Chemical Composition:
$C_6H_3N_5O_6$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Metanitroaniline

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Ensign Bickford Industries Inc., under contract to the U.S. government, is developing a pilot-production process; Aerojet, Hercules, and Navy laboratories are among those also developing the producibility of ADNBF.
Ensign Bickford address:
660 Hopmeadow St.,
P.O. Box 427, Simsbury CT 06070-0427
Tel: (203) 843-2225
FAX:(203) 843-2621
Contact: Mr. Pete McGuinness

14. Production Capacity: About 200 lbs per batch	**15. Cost:** Target cost is $10 per lb

16. Shipping Pack & Label:
No UN Hazard Class assigned; nominally a Class 1.1 explosive.

17. Color & Form:
White crystals

18. Foreign Producers:
Dept. of Chemical Engineering, Beijing Inst. of Technology, China.

19. Foreign Capacities:
Experimental quantities.

20. Military Uses:
Low vulnerability booster explosive; and ingredient of non-metallized missile propellants with reduced plume signatures.

21. Civil Uses:
None

22. Notes:
Aminodinitrobenzofuroxan is a new explosive, listed in the MCTL since 1989 and included in ML 8 in 1992. New high energy binder technology is critical for the success of these developments.

CH synthesized a related substance 5-methylamino-4,6-dinitrobenzofuroxan in the 1970s and is apparently now investigating ADNBF. Its existence was published at a meeting in California in 1986 attended by the following NATO countries: Canada, UK, France, GE, Norway, Italy, Netherlands, Japan, and Belgium. Attendees from Sweden, Switzerland, Singapore, and CH were also in the audience. None is known to be developing production capabilities. In August 1989 a paper on the properties of energetic benzofuroxans, including ADNBF, was presented before an audience, including representatives from the then Warsaw Pact countries. The substance has been synthesized in China (Ref. 1). However, no country other than the U.S. is known to be developing production technology, although all or most have the technological know-how to do so. The related diamino compound, known by the acronym CL-14, is more energetic and less sensitive than ADNBF.

23. References/MILSPECS:

1. Boren Chen, Zhiyuan Liao. 21st. International Conference of ICT, Fraunhofer-Inst. für Chemische Technologie, Karlsruhe, Germany, 1990, pp. 58-1-4.

1. Substance or Composition: Alcohol-functionalized polyepichlorohydrin	**3. Molecular Structure:**
2. CAS Registry No.: Not registrable	
4 Acronym(s) or Trade Designation(s): Dynamar™, HX-102	
5. Synonyms: polyepichlorohydrin diol; polyepichlorohydrin triol	
6. Chemical Composition:	
7. Control Status: Controlled by ML-8 Note 5; USML CAT V §121.12	
8. Quality: Not specified	
9 Precursors: Low molecular weight (≈ 2000)poly-epichlorohydrin	
10. Precursor Quality: NS, except < 2000 molecular weight	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: 3M Company, Specialty Chemicals Div., 3M Center, 236-2A-01, St. Paul MN 55144-1000. Tel: 612 458-1392; FAX: (612) 458-1383. Dr. Anthony P. Manzara	
14. Production Capacity: Developmental quantities.	**15. Cost:** Not availabe
16. Shipping Pack & Label: Sealed 50 lb units, with one year minimum storage life.	
17. Color & Form: Pale yellow to amber liquid; surface darkening may occur.	

18. Foreign Producers:
? Canada; Japan.

19. Foreign Capacities:
Developmental quantities only.

20. Military Uses:
A pre polymer for the formulation of cast polyurethane propellants

21. Civil Uses:
Unknown

22. Notes:
Low molecular weight, alcohol-functionalized polyepichlorohydrin is required as a precursor for energetic binders for propellants and high explosives and is not believed to be available outside the United States, although undifferentiated epichlorohydrin and polymers are widely available throughout the world. Japan (Nippon Oil and Fats) has prepared GAP for use in missile propellants, but the source of the polyepichlorohydrin has not been determined (possibly Diacel Chemical Co., Japan). See also the notes about GAP for a possible Canadian source of epichlorohydrin for GAP.

23. References/MILSPECS:

1. Substance or Composition: Alkyl-propyl trimethylol propane	**3. Molecular Structure:** Unknown
2. CAS Registry No.: Unknown	
4. Acronym(s) or Trade Designation(s): Unknown	
5. Synonyms: None	
6. Chemical Composition: Unknown	
7. Control Status: Not controlled; listed in 1992 MCTL	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: National Starch for Kenrich Petrochemicals, Inc. 140 E. 22nd St., Bayonne NJ 07002-0032. Tel: 201-823-9000; Fax 201-823-0691. POC: Mr. Sal. Monte, President.	
14. Production Capacity: 100,000 lb per day	**15. Cost:** Not available
16. Shipping Pack & Label: Not available	
17. Color & Form: Not available	
18. Foreign Producers: None	

19.	**Foreign Capacities:** None
20.	**Military Uses:** Manufacture of titanate coupling agents
21.	**Civil Uses:** Manufacture of titanate coupling agents
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition:
Alloys of zirconium, boron, magnesium

2. CAS Registry No.:
Not registrable

4. Acronym(s) or Trade Designation(s):

3. Molecular Structure:

Not available

5. Synonyms:
Zirconium boride; magnesium boride.

6. Chemical Composition:
Zr-B, or Mg-B; or Zr-Mg-B

7. Control Status:
Controlled by MTCR

8. Quality:
Particle sizes <500 micro-meters, whether spherical, atomized, spheroidal, flaked , or ground consisting of 97% by weight or more of the alloys

9. Precursors:
Powdered refractory metals and boron powder

10. Precursor Quality:
Not specified

11. Production Process:
High temperature reaction of respective metal with boron; crushing and grinding

12. Production Equipment:

13. U.S. Producers:
Norton Company

14. Production Capacity:
Limited

15. Cost:
>$200/lb.

16. Shipping Pack & Label:
UN Hazard Class 4

17. Color & Form:
Dark gray metallic powders

18. Foreign Producers:
Austria? Germany? FSU?

19. Foreign Capacities:
Unknown

20.	**Military Uses:** Missile propellant ingredients; powders used to make refractory components for turbine blades, nozzles, etc.
21.	**Civil Uses:** Refractory hard metal applications
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition: Aluminum powder	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: 7429-90-5	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms: Aluminium powder	
6. Chemical Composition: Al	
7. Control Status: a. Controlled by ML-8 Note 1a; USML CAT V §121.12; b. Controlled by MTCR	
8. Quality: a. Spherical powder of particles size 60 µm or less (ML-8, USML V). b. Spherical powder with particles of uniform dia. of <500 µm (MTCR)	
9. Precursors: Aluminum stock (Ingots)	
10. Precursor Quality: a. Aluminum greater than 99% purity; b. Aluminum stock with content of 97% by weight or greater of Al	
11. Production Process: Spherical particles are produced by atomization, the forcing of aluminum through nozzles in an inert atmosphere. Valimet uses a helium atmosphere; others use nitrogen.	
12. Production Equipment: Atomization plant capable of working in nitrogen or an inert atmosphere; rapid-cooling plant to produce spherical grains.	

13. U.S. Producers:

(1) Valimet Inc.,
431 E. Sperry Road,
Stockton CA 95206
Tel: (209) 982-4870;
FAX: (209) 982-1365
Contact: Mr. D. Tygett, VP, Sales & Marketing

(2) Alcan-Toyo America,
1717 Napier Blvd., Suite 201,
Napierville IL 60540
Tel: (708) 505-2170
FAX: (708) 505-2176
Peter Ortleb, President. (Plant is in Joliet IL)

(3) Reynolds, Rockdale, TX;

(4) Alcoa, Louisville, KY;

14. Production Capacity:

a. 400,000 lb per year;
b. The current total capacity for spherical Al is virtually unlimited: Valimet and Alcan-Toyo produce an estimated 4-5 million lb per year; but Alcoa could if it chose run its plant (rated at 30,000 tons) under nitrogen (see notes).

15. Cost:

a. $ 2.00-$7.00 per lb
b. >$1.50 per lb (see notes)

16. Shipping Pack & Label:

UN Class 4.3

17. Color & Form:

Gray powder

18. Foreign Producers:

Toyo, Japan (does not currently make spherical)
Cegedur Pechine, France;
Schlenk, Germany;
Eckert, Germany (one plant in Spain; one in Bahrain has a high production of air-atomized);
Alpoco, UK (sells spherical in Europe);
CIS (sells spherical powders and ingots in U.S. and elsewhere);
SLAM Atomized Metals SDN, BHD, Malaysia (offers spherical worldwide);
China (makes spherical)

19. Foreign Capacities:

Significant

20. Military Uses:

A solid propellant fuel mixed with HMX and AP(q.v.); or an ingredient of blast-enhanced high explosives mixed with TNT, RDX and/or ammonium nitrate.

21. Civil Uses:

Spherical powders are used for:
Aluminum pigment manufacture;
Thermal spray applications;
Metal matrix composites;
Brazing compounds;
Chemical and thermite reactions;
Propellant ingredient for commercial launch vehicles: ELV, Pegasus, Delta.
Commercial explosives and pyrotechnics.

22. Notes:

Significant changes have occurred in the control levels and in the U.S. and foreign availability of spherical Al in recent years. During the 1987-8 period the upper limit on the control level listed in ML-8 was reduced to 60μm from 300μm. Subsequently, the same change was introduced into the USML; but the MTCR introduced a control level of 500μ, thus broadening further what had previously been assessed by NATO to be an overly broad coverage.

The services, particularly the USAF, was at that time primarily concerned about control of the >60μm, high purity product, and particularly cuts of >3μm size. While there were other potential U.S. producers, such as Reynolds and Alcoa, the past quality of their products was not considered to match the quality of Valimet material. Since 1982 the demand for the product by the military has decreased, but the demand for civil purposes has increased, so that military applications no longer dominate the market for the listed material. New or increased foreign sources of supply have also emerged, creating an over-capacity internationally for atomized aluminum. This resulted in a reduction of the cost of the material, placing Western countries at an economic disadvantage. Although demand has again increased in the civil market, US companies, in particular, have been restricted by export licensing procedures from benefiting materially from the situation. Valimet considers that the licensing procedures alone have cost the company $500,000 a year for the past five years at least.

The basis for the introduction of the broader coverage is not clear because no use of material of this size in propellant systems has been identified; its use for civil applications is likewise limited. Rather, small-sized, angular material has been used in place of spherical materials in both military and civil, U.S. and foreign, missile systems. Three types of aluminum powder are used for U.S. munitions applications, and these are covered by four military specifications, with several grades within each specification:

MILSTD	GRADE		
	Purity	Micrometers	Grain
512A	85-98.75%	20 - 30	Flaked, grained or atomized
82728	>98.5%	11 - 27	Air atomized
23950A	98% Min.	4.5 - 9.0	
		12.0 - 18.0	Spherical, inert gas atomized
		25 - 30	
81335	99%	22 ± 5	Spherical, inert gas atomized

(Cont.)

22. Notes (Cont.):

The air-atomized, granular material is used, for example, in the MLRS, Titan, and the space shuttle. It can be produced in various quantities by all the U.S./NATO manufacturers shown. The Minuteman, Trident, Standard, and Patriot are other, but decreasing consumers of higher grade, spherical materials.

According to the USAF in 1988, the sole consistent producer of the spherical material in the U.S. was the Valimet Corporation. Other U.S. producers (Alcoa, who furnish the shuttle fuel, and Reynolds) were reported to have difficulty meeting the Valimet quality; Alcan-Toyo(Canada) is now reported to produce this quality. The purity of Valimet's starting material is 99.7%; the quoted purity of the spherical material depends on the manner in which the oxide content of the surfaces is assayed.

The total U.S. production of spherical, non-spherical, flaked or ground aluminum powder for civil applications and military specifications was estimated by the Aluminum Association to be about 89,400,000 lb per year in 1993 at a cost of \$1.00 - 3.00 per lb., compared with the 1982 estimate of 143,000,000 lb.

The U.S. annual production in 1993 for the different types was estimated to be 71.5(99) million atomized, 15.3(36) million "paste," and 2.6(8) million flaked (Estimates for 1982 in parenthesis). During 1993, 11.1% (8.1 million lb) of the atomized was used for military and aerospace purposes; the remainder was used by commercial companies for chemical process industries (28.2 million lb), paints and fillers (8.1 million lb), metallurgy (15.9 million pounds), and other miscellaneous purposes (4.3 million lb); a further 6.9 million lb were exported.

Most of the military/aerospace material is consumed by the shuttle, using over 400,000 lb per launch and about 10 launches per year; and by Titan (300,000 lb per launch). Estimated maximum U.S. military requirements are about 3.5-4.0 million lb/year (<5% of total atomized)), with the demand varying depending primarily on the status of Peacekeeper, Trident II, and SICBM programs; currently they require probably not more than 1 million lb/year, and the amount is decreasing.

Demand for the spherical powder for use in high explosive formulations also continues; for example, 6-9μ material is used in new insensitive general purpose bombs; and 3μ material is used in insensitive underwater explosives, along with AP (44.8%) and TMETN (18.8%).
Product costs are estimated to be \$1.00 per lb for all but the inert gas-atomized material; the latter cost varies from about \$2.00(3.00) per lb for 30-40 μm material to \$7.00(10.00) per lb for 3 μm powder (1988 costs in parenthesis).

Some of the spherical powder is exported to Korea and Taiwan for the licensed missile programs, but the vast majority is exported for commercial applications.

Most foreign producers have the technical basis for producing spherical grains, lacking perhaps only the rapid cooling required to produce them from the liquid phase. In 1988 Valimet ventured the opinion that any superiority their product has for missile technology lies in their skill at producing closely defined size fractions within the overall military specifications for spherical material. Any producer of aluminum by air atomization is a potential producer of spherical powders; it is necessary merely to replace the air with nitrogen or an inert gas. Valimet only produces helium-atomized powders. A medium-sized, 5-10 million air/inert atomizer can be built for about \$3-5 million; a fully inert plant would be more costly. **(Cont.)**

22. Notes (Cont.):

The lack of this quality can be offset by the expertise of the solid propellant formulator in processing spherical ammonium perchlorate grains to blend with the aluminum. Once a missile propellant has been developed and qualified for a given system, the high cost of re-qualifying the system with the products of another company is a serious deterrent to the development of alternative sources of supply. This may be one reason why potential manufacturers do not produce the spherical grade. Another reason is that the systems under development and in production in other countries do not require the precision performance characteristic of the most powerful, U.S. strategic and tactical missiles.

23. References/MILSPECS:

MIL-A-512A, MIL-A-82728, MIL-A-23950, MIL-A-81336

1. Substance or Composition: Aluminum octadecanoate	**3. Molecular Structure:** Unknown
2. CAS Registry No.: 637-12-7	
4. Acronym(s) or Trade Designation(s): Octal	

5. Synonyms:
Aluminum stearate;
Aluminum tristearate

6. Chemical Composition:
$Al(C_{18}H_{35}O_2)$; or
$Al(C_{18}H_{35}O_2)_{1.5}$; or
$Al(C_{18}H_{35}O_2)_3$

7. Control Status:
Controlled by ML-8 Note 4; USML CAT V §121.13

8. Quality:
Not specified

9. Precursors:
See process below

10. Precursor Quality:
Not specified

11. Production Process:
Stearic acid exists as a natural glyceride in tallow, other animal fats and some vegetable oils, and is obtained by hydrolyzing with steam and a catalyst raw stock, and by distilling. Octal is produced by reaction of Al or Al hydroxide with stearic acid or with Na stearate.

12. Production Equipment:
Proprietary

13. U.S. Producers:
Unknown

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label:
Drums

17. Color & Form:
White powder

18.	**Foreign Producers:** UK
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Ingredient of Napalm, and gelling agent for flame-thrower fuels.
21.	**Civil Uses:** See notes.
22.	**Notes:** See notes for military fuel thickeners.
23.	**References/MILSPECS:** "Stearic Acid, Technical". MIL SPEC-271B (1962).

1. Substance or Composition: Amine-based antioxidants	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: Not registrable	
4. Acronym(s) or Trade Designation(s): Series 3000, Protech™ antioxidants and stabilizers	
5. Synonyms: None	
6. Chemical Composition: Various	
7. Control Status: Controlled by USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: MACH I Inc., 346 East Church Rd., King of Prussia PA 19406; Tel: (215) 279-2340. POC: Bernard M. Kosowski, President	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label: Unknown	
17. Color & Form: Not specified	
18. Foreign Producers: None	

19.	**Foreign Capacities:** None
20.	**Military Uses:** Stabilizer-scavengers (anti-oxidants) for missile propellants
21.	**Civil Uses:** None
22.	**Notes:** Phenol- and amine-based compounds and mixes are used in quantities up to about 0.1% of propellant compositions. Their function is to extend pot life and promote long term stability in polymer-bonded propellants while they are being mixed and cast, or are in long term storage in missile and rocket propulsion systems. They are stable indefinitely under normal storage conditions, but are added early in the propellant mix process, after which premixes must be used promptly. Specific stabilizer formulations are adapted to different propellant compositions, and particularly to the presence of other additives, such as iron oxide or catocene, and the nature of the polymer, such as polyurethane or GAP. The adaptations are identified by different serial numbers, the phenol-based being series 2000 items, and the amine-based bein g series 3000 items. They are expensive combinations of materials uniquely tailored to provide essential stability to some of the most important U.S. rocket propellants; they are easily reverse-engineered, and the subject of significant foreign interest. The substances are not listed in the ML, but are listed simply as Protech under the Additives of USML CAT V, §121.12.
23.	**References/MILSPECS:**

1. Substance or Composition: Ammonium dinitramide	**3. Molecular Structure:** $NH_4^+N(NO_2)_2^-$
2. CAS Registry No.: 140456-78-6	
4. Acronym(s) or Trade Designation(s): ADN or SR-12	
5. Synonyms: Non	
6. Chemical Composition: $N_4H_4O_4$	
7. Control Status: Controlled by ML-8 Note 1a; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Proprietary	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: SRI International, 333 Ravenswood Ave., Menlo Park CA 94025. Tel: (415) 859-2430; FAX: (415) 859-4321. Dr. Robert J. Schmitt.	
14. Production Capacity: Pilot scale development	**15. Cost:** Not available
16. Shipping Pack & Label: UN Hazard Class 1.2 or 1.3	
17. Color & Form: White crystals	
18. Foreign Producers: FSU	

19. Foreign Capacities:
Significant

20. Military Uses:
Potential fuel-oxidizer for strategic missile or other solid fuel propulsion systems, with reduced signature.

21. Civil Uses:
Potential fuel-oxidizer for space-shuttle propulsion systems.

22. Notes:
A potential ingredient for missile propellants, ADN or SR-12 is a more energetic replacement for AP. It also has the advantage of not releasing HCl in the atmosphere when used as a solid missile propellant, thus providing reduced signatures and environmental benefits. The process for its manufacture is also being scaled up.

It is reported that there has been an FSU awareness of ADN since the 1970s, details of which were given at an AIAA meeting in 1993 (Ref. 1). It is possible the FSU is the leader in the technology of ADN. Assessments by MICOM and BD are underway.

23. References/MILSPECS:

1. Z. Pak. *Some Ways to Environmental Safety of Solid Rocket Propellant Applications* AIAA-93-1755. Monterey CA. June 28-30, 1993.

1. Substance or Composition:
Ammonium perchlorate

2. CAS Registry No.:
7790-98-9

3. Molecular Structure:

4. Acronym(s) or Trade Designation(s):
AP

5. Synonyms:
Perchlorat d'ammonium (Fr); Ammonium perchlorat (Ger); Perclorato di ammonio (It); Amonio perclorato (Sp); Perkhlorata ammoniya (Rus)

6. Chemical Composition:
NH_4ClO_4

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR

8. Quality:
Not specified; but solid propellants generally require a particle size $<2\mu$ and >99% purity..

9. Precursors:
Sodium perchlorate and ammonia or ammonium chloride

10. Precursor Quality:
Not specified

11. Production Process:
Sodium perchlorate is produced by electrolysis of sodium chlorate using platinum on Cu or Ti anodes, or by reaction of sodium perchlorate with ammonia or ammonium chloride. Neutralization of ammonia with perchloric acid. Fine particle AP may require a coating to prevent recrystallization in air.

12. Production Equipment:
Ultrafine AP required for solid propellants requires a jet mill (such as model 0202 Jet-o-mizer with a capacity of greater than 8 lb./hr); or slurry grinding in Freon in a Sweco Vibro energy mill for 160 hr, giving a particle size of 1-2μ.(See also Ref. 1)

13. U.S. Producers:
a. Kerr McGee, Henderson NV;
b. WECCO, Cedar City, UT

14. Production Capacity:
a. 16,000 metric tonnes per year;
b. 13,500 metric tonnes per year

15. Cost:
$2.05 per kg

16. Shipping Pack & Label:
UN Hazard Class 1.1 or 5.1 depending on particle size, etc.. and packaging; the boundaries are not firmly established.

17. Color & Form:
White or colorless crystals

18. Foreign Producers:

a. Atochem, Jarrie, France;
b. Societé Nationale des Poudres et Explosifs, France. Processors; may not be producers;
c. Pechinney, France ;
d. Japan Carlit;
e. ERDE, Waltham Abbey, UK;
f. SNIA-BPD, Colleferro, Italy. Processors; may not be producers
g. Bayern Chemie, Germany. Processors; may not be producers
h. Abu Zaabal, Egypt
i. Iran
j. Alvitras, San Jose, Brazil
k. Israel
l. Switzerland
m. Former Yugoslavia
n. Chung Cheng Institute of Technology Taiwan. Processors; may not be producers

The U.S. has in the past sold AP to Argentina, Australia, Brazil, Israel, Mexico, and South Korea. Requests for technology or licenses have also come from Brazil, India, Pakistan, CH, and South Africa. These requirements and requests may indicate that additional capabilities are to found among them.

19. Foreign Capacities:
Referenced to box 18 above:

c. 8000 tonnes/year as sodium perchlorate increasing to 16,000 tons/year by 1990 Cost $4.40 per kg;
d. 3000 tonnes/year. Cost $8.80 per kg.
e. <100 tonnes/year (produced also for fireworks and laboratory tests in private industry
h. 500 tonnes/year (U.S. delivered plant in 1970)
i. Claimed at SECARM exhibit, Libreville, Gabon (Ref. 2)
j. Capacity not identified (in operation since 1987) (Ref. 3)
k. 5–10 tonnes/year
l. 350 tonnes/year
m. 500 tonnes/year

20. Military Uses:
Ingredient of solid propellants for missiles; ingredient of underwater, high explosive charges for torpedo warheads or sea mines. (See notes for requirements for different types of missile system.)

21. Civil Uses:
Commercial space launch systems

22. Notes:

AP's preparation and use in formulations date back to 1831 and the 1880s, respectively, while commercial, electrolytic methods of preparation date to the 1890s. Common salt is first oxidized electrolytically to form the chlorate and this in turn is oxidized to form the perchlorate. The sodium perchlorate is then reacted with ammonia or ammonium chloride to form ammonium perchlorate. The bulk product requires further processing to produce crystals of a purity, shape, and particle size distribution acceptable for the more exacting requirements of missile propulsion. The products normally require further processing by aerospace contractors, and commonly the products of different manufacturers in the U.S. are not used interchangeably for a specific propulsion system without re-qualification testing. Other countries may be less exacting in their requirements, but it may be assumed that the bulk products available on world markets are also only crudely interchangeable with the refined products of particular U.S. manufacturers. The quantity of AP required for munitions or weapons systems varies from a few lbs or kgs for an infantry support missile, to 1000 lbs (0.45 metric tonnes) for a medium-range missile, to over 40,000 lbs (20 metric tonnes) per launch of a long-range ballistic missile. Titan IV consumes about 440 tonnes per launch, while the NASA space shuttle consumes about 700 tonnes per launch. These requirements place heavy demands on available U.S. production capacity.

AP is also an ingredient in the most blast-effective underwater explosives, and water gel explosives. During the Southeast Asia operations, it was also considered as a substitute for TNT in general-purpose bombs and other high-use munitions. Analyses conducted at that time concluded that the availability of platinum, a strategic material and the most effective anode material (consumed in the electrolytic preparation of sodium perchlorate), would place constraints on the availability of AP in the U.S. It was recommended that AP capacity be reserved for missile propellant applications, and if used in high explosive compositions, this be confined to underwater explosives.

U.S./NATO production capacities have increased since that time. Development work is under way to reclaim excess AP from production mixes and blend the reclaimed materials into new production lots. Known NATO producers were increasing production in the 1990s

It should be noted that a potentially more powerful replacement for AP is under development in the U.S. (see SR-12). Details of the FSU's manufacturing processes and capacities are not known. However, they have been researching inorganic perchlorates since the late 1940s, and have applied AP in munitions and weapons systems for over 25 years. Manufacturing capabilities existed at least in the FSU, Czechoslovakia, and at IG Farben, Bitterfeld, the former GDR. There is little to indicate the processes used; the processes used in the U.S./NATO are well known internationally, and the FSU has indigenous sources of platinum and precursor materials for the sodium perchlorate production. AP propellants are among formulations used for munitions exported from the former FSU to Egypt and the Middle East.

Apart from shipments to most NATO countries, U.S. manufacturers have sold AP to Argentina, Australia, Brazil, Israel, Mexico, and South Korea. Requests for technology or licenses have come from Brazil, India, Pakistan, CH, and South Africa. Several of these countries have laboratory or pilot plant capabilities that are associated with developing missile propulsion industries. Taiwan has such a capability at Chung Cheng Institute of Technology and has developed a fluidized bed process for preparing porous AP of various particle sizes.

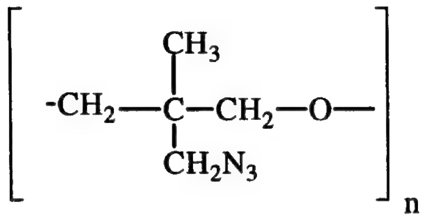
23. References/MILSPECS:

1. MILSPECs: AP 99.3% MIL-A-23442; AP Technical, 99%, MIL-A-192B; AP for solid propellant grains; MIL-A-23946; AP, special, coarse for solid propellant grains MIL-A-23948
2. *Janes Defence Weekly*, p. 219, 11 February 1989.
3. TWG 9-B Meeting, Aerojet Solid Propulsion Co, Sacramento, CA, 10-11 February 1988.

1. Substance or Composition:
Azidomethylmethyloxetane

2. CAS Registry No.:
Not registered

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
AMMO

5. Synonyms:
2-methyl-2-azidomethyl-4-oxacyclobutane

6. Chemical Composition:
$C_5H_9N_3O$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9 Precursors:
Bischloromethyloxetane

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Unknown

14. Production Capacity:
Unknown

15. Cost:
Not available

16. Shipping Pack & Label:
Unknown

17. Color & Form:

18. Foreign Producers:
Japan

19. Foreign Capacities:
Limited

20. Military Uses:
Energetic binder for missile propellants

21. Civil Uses:
None

22. Notes:
AMMO is intended, as an alternative to NMMO (qv), for use with nitrates of polyhydric alcohols (PEG, PEP, TMETN, BTTN, etc.) or oxetane alcohol monomers for new medium energy propellants, or with NG for high energy propellants.

The Japanese Defense Agency is evaluating AMMO, as part of their search for energetic binder materials. AMMO (20%), the most thermally stable azide binder polymer, changes the crystalline form of AP (80%) from orthorhombic to cubic. The formulation was cured with isophoron diisocynate (IPDI) at 333 K for 10 days. Trimethylol propane (TMP) was used as a cross-linking agent and 2% ferric oxide (Fe_2O_3) or catocene 2,2-bis(ethylferrocenyl)propane; were used as burning rate modifiers (Ref. 1)

23. References/MILSPECS:

1. Oyumi, Y., Y. Mitarai, and H. Bazaki, *Propellants, Explos., Pyrotech.* 1993, 18, 168.

1. Substance or Composition: Basic copper salicylate **2. CAS Registry No.:** 62320-94-9 **4. Acronym(s) or Trade Designation(s):**	**3. Molecular Structure:** Unknown

5. Synonyms:
Mono-basic copper salicylate

6. Chemical Composition:
$C_6H_4(CO_2)CuH_2O$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9 Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
The Shepherd Chemical Co.
4900 Beech St.,
Cincinnati OH 45212
Tel: (513) 731 1110;
Fax (513) 731-1532.
Mr Bayard Pelser.

14. Production Capacity: Not available	**15. Cost:** Not available

16. Shipping Pack & Label:
Not specified

17. Color & Form:
Not specified

18. Foreign Producers:
None

19.	**Foreign Capacities:** None
20.	**Military Uses:** Ballistic modifier for missile propellants similar to lead beta resorcylate.
21.	**Civil Uses:** Unknown
22.	**Notes:** There are known foreign producers of lead and copper malates, stannates, salicylates, etc. Their application was originally of FSU origin, and they have been proposed for deletion from control lists. They are no longer listed in the MTCR.
23.	**References/MILSPECS:**

1. Substance or Composition: Beryllium	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: 7440-41-7	
4 Acronym(s) or Trade Designation(s): a. Brush S200-F b. Brush Guidance Specs.: I-220 and I-400	
5. Synonyms:	
6. Chemical Composition: Be	
7. Control Status: a. Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR b. Controlled by MTCR	
8. Quality: a. Powders in particle sizes less than 60 micrometers whether spherical, atomized, spheroidal, flaked, [sponge], or ground. b. Particle sizes <500 micrometers, whether spherical, atomized, spheroidal, flaked , or ground consisting of 97% by weight or more of Be.	
9. Precursors: Beryllium stock a. 99% or greater purity b. 97% or greater purity; and from beryl ore from manufacturer's mine in Utah	
10. Precursor Quality: Not specified	
11. Production Process: Electrolysis of fused Be chloride with Na or ammonium chlorides; or of fluoride with NaF in nickel vessels with carbon anode	
12. Production Equipment: Not specified	
13. U.S. Producers: Brush-Wellman, Inc., 17876 St. Clair Ave, Cleveland OH 44110 Tel: (800) 321-2076; (216) 383-4091; FAX: (216) 383-4091. Plant is at Elmore OH. Tel: (419)862-4321(Hugh Hanes), or (419) 862-4341(Larry Ryczek)	
14. Production Capacity: a. 300,000 lb./ year b. >300,000 lb./ year	**15. Cost:** $225-400 per lb.

16.	**Shipping Pack & Label:** UN Class 6.1, Toxic powder; or Class 4.1, Flammable solid (subsidiary risk).
17.	**Color & Form:** Gray metal powder
18.	**Foreign Producers:** Kazakhstan
19.	**Foreign Capacities:**
20.	**Military Uses:** Experimental solid propellant fuel; powder can also be processed to fabricate structural elements of strategic missiles (e.g. Minuteman) and their guidance systems.
21.	**Civil Uses:** Fabricate X-ray windows
22.	**Notes:** Material has been exported to French AEC and to UK
23.	**References/MILSPECS:**

1. Substance or Composition:
Beryllium Hydride

2. CAS Registry No.:
7787-52-2

3. Molecular Structure:
Not applicable

4. Acronym(s) or Trade Designation(s):

5. Synonyms:

6. Chemical Composition:
Be—H, or BeH_2

7. Control Status:
Not controlled, but an item of interest

8. Quality:
Not specified

9. Precursors:
Beryllium metal powder

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Brush-Wellman, Inc.,
17876 St. Clair Ave,
Cleveland OH 44110
Tel: (800) 321-2076; (216) 383-4091; FAX: (216) 383-4091.
Plant is at Elmore OH. Tel: (419)862-4321(Hugh Hanes),
or (419) 862-4341(Larry Ryczek)

14. Production Capacity:
Total production a few hundred lb. Not now (1995) in production.

15. Cost:
>$1,000,000 per production lot

16. Shipping Pack & Label:
Hazard classification not determined; but at least Class 4, if not a Class 6, toxic substance

17. Color & Form:
Very fluffy gray powder

18. Foreign Producers:
None known

19.	**Foreign Capacities:**
20.	**Military Uses:** Experimental solid propellant fuel .
21.	**Civil Uses:** None
22.	**Notes:** Proposed for inclusion by Thiokol, Elkton Div. 21 JUL 1994 and by MICOM (Ref. 1.). Contract to produce the material canceled in about 1990. It is reported to be stored at Rocky Flats, CO or Edwards AFB, CA. (Ref. also: Shawn Barnett, IDA, and study of Be foreign capabilities) (Ref. 2)
23.	**References/MILSPECS:** 1. Letter to government industry advisory group, 14 AUG 1994. 2. Brush-Wellman Inc. to government/industry advisory group, 2/10/95.

1. Substance or Composition: Bis(2,2,2-trinitroethyl-N-nitro)ethylene diamine	**3. Molecular Structure:** Unknown
2. CAS Registry No.: Unknown	
4. Acronym(s) or Trade Designation(s): ZOX	
5. Synonyms: None	
6. Chemical Composition: $C_6H_8N_{10}O_{16}$	
7. Control Status: Not controlled; but of interest.	
8. Quality: Not specified	
9. Precursors: Nitroform	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: None	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label: UN Hazard Class 1.1 Explosive	
17. Color & Form: White crystals	
18. Foreign Producers: China; Russia ?	
19. Foreign Capacities:	

20.	**Military Uses:** See notes.
21.	**Civil Uses:** None
22.	**Notes:** ZOX was first synthesized by the FSU in 1952 by Avansov and has undergone development in CH since it was prepared there in 1964 or earlier. It has apparently not been exploited in any NATO country, but is a possible alternative to CP or BNCP. ZOX is reported to have an above average density of 1.87 g/ml, a detonation velocity of 8970 m/s, and a sensitivity that permits it to be used in formulations for exploding bridgewire detonators. Its possible application in nuclear weapons and missile technology may be presumed. Furthermore, ZOX has been used as an ingredient along with AP, aluminum, a polymeric binder and burning rate modifier to yield rocket propellants with theoretical specific impulses in the range of 268-273.6 s. Because nitroform is a reactant used to form ZOX it must be concluded that CH has access to a nitroform source.
23.	**References/MILSPECS:**

1. Substance or Composition:
Bis(2,2-dinitropropyl) acetal

2. CAS Registry No.:
5108-69-0

3. Molecular Structure:

$$CH_3CH\left[OCH_2\,C(NO_2)_2\,CH_3\right]_2$$

4. Acronym(s) or Trade Designation(s):
BDNPA

5. Synonyms:
1,1-bis(2,2-dinitropropoxylene);
2,2,8,8-tetranitro-5-methyl-2,4-dioxanonane

6. Chemical Composition:
$C_8H_{14}N_4O_{10}$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9 Precursors:
Dinitropropylol (DNPOH)(made by Thiokol); nitroethane; CH_2O; nitric acid; organic solvent.

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Thiokol Corp.
Ordnance Operations
PO Box 1092
Marshall TX 75671
Contact: Mr. R .E Jones
Tel:(903) 679-2333
FAX: (903) 679-2869

14. Production Capacity:
Pilot plant

15. Cost:
Not available

16. Shipping Pack & Label:
UN Hazard Class 1.1 explosive

17. Color & Form:
Straw colored liquid

18. Foreign Producers:
FSU
Taiwan
UK

19. Foreign Capacities:
At least pilot plant quantities

20. Military Uses:
Used as a nitroplasticizer with or without BDNPA for high performance high explosives.

21. Civil Uses:
None

22. Notes:
The FSU probably produces the widely available, energetic plasticizers BDNPF (bis(2,2-dinitropropyl)formal) and BDNPA (bis(2,2-dinitropropyl)acetal) that have been in use for some 20 years in the United States.

Taiwan is able to make at least small quantities of the prepolymer for studies of GAP/BDNPA/BDNPF stability (Ref. 1)

23. References/MILSPECS:

1. An-Lu Leu, Shin-Ming Shen, et al. *Proceedings of 21st. International Conference of Fraunhofer Institute of Chemical Technologie*, Karlsruhe, Germany 1990, p. 6-1.

1. Substance or Composition: Bis(2,2-dinitropropyl) formal	**3. Molecular Structure:** $CH_2[OCH_2\ C(NO_2)_2\ CH_3]_2$
2. CAS Registry No.: 5917-61-3	
4. Acronym(s) or Trade Designation(s): BDNPF	

5. Synonyms:
2,2,8,8-tetranitro-4,6-dioxanonane

6. Chemical Composition:
$C_7H_{12}N_4O_{10}$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Thiokol Corp.
Ordnance Operations
PO Box 1092
Marshall TX 75671
Contact: Mr. R. E Jones
Tel:(903) 679-2333
FAX: (903) 679-2869

14. Production Capacity: Pilot plant	**15. Cost:** Not available

16. Shipping Pack & Label:
Unknown

17. Color & Form:
Straw colored liquid

18. Foreign Producers:
FSU, Taiwan, Japan?

19. Foreign Capacities:
Unknown

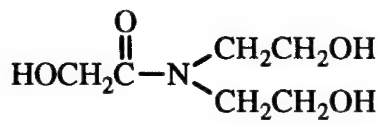
20. Military Uses:
Used as a nitroplasticizer with or without BDNPA for high performance high explosives

21. Civil Uses:
None

22. Notes:
The FSU probably produces the widely available, energetic plasticizers BDNPF (bis(2,2-dinitropropyl)formal) and BDNPA (bis(2,2-dinitropropyl)acetal) that have been in use for some 20 years in the United States.

Taiwan is able to make at least small quantities of the prepolymer for studies of GAP/BDNPA/BDNPF stability (Ref. 1)

23. References/MILSPECS:
1. An-Lu Leu, Shin-Ming Shen, et al. *Proceedings of 21st. International Conference of Fraunhofer Institute of Chemical Technologie*, Karlsruhe, Germany 1990, p. 6-1.

1. Substance or Composition: Bis(2-hydroxyethyl)glycolamide	**3. Molecular Structure:** 
2. CAS Registry No.: 17409-41-5	
4. Acronym(s) or Trade Designation(s): BHEGA, or HX-880	

5. Synonyms:

6. Chemical Composition:
$C_6H_{15}NO_4$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
3M Company, Specialty Chemicals Div.,
3M Center, 236-2A-01,
St. Paul MN 55144-1000.
Tel: 612 458-1392;
FAX: (612) 458-1383.
Dr. Anthony P. Manzara

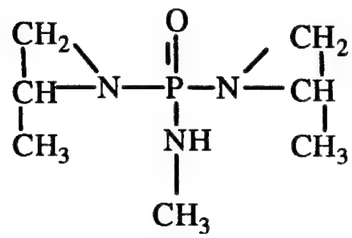
14. Production Capacity: About 100 lb per year	**15. Cost:** Not available

16. Shipping Pack & Label:
Drums

17. Color & Form:

18. Foreign Producers:
None

19. Foreign Capacities: None	
20. Military Uses: A bonding agent for use with HTPB in missile propellants	
21. Civil Uses: None	
22. Notes:	
23. References/MILSPECS:	

1. Substance or Composition: Bis(2-methyl aziridinyl) methylamino phosphine oxide	**3. Molecular Structure:** 
2. CAS Registry No.: 85068-72-0	
4. Acronym(s) or Trade Designation(s): Methyl BAPO	

5. Synonyms:

6. Chemical Composition:
$C_7H_{16}N_3OP$

7. Control Status:
Controlled by ML-8 Note 2

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
See notes

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label:
Drums

17. Color & Form:
Not available

18. Foreign Producers:
SNPE, France

19. Foreign Capacities:
Unknown

20. Military Uses:
Bonding agent for missile propellants

21. Civil Uses:
Not determined

22. Notes:
France (SNPE) has developed this analog of MAPO that it is endeavoring to market within NATO countries, and perhaps elsewhere. It is an alternative bonding agent for use with missile propellant ingredients. The source of the MAPO, if used as a precursor, has not been determined. The following is a potential source of current information on the product:

3M Company, Specialty Chemicals Div.,
3M Center, 236-2A-01,
St. Paul MN 55144-1000.
Tel: 612 458-1392;
FAX: (612) 458-1383.
Dr. Anthony P. Manzara

23. References/MILSPECS:

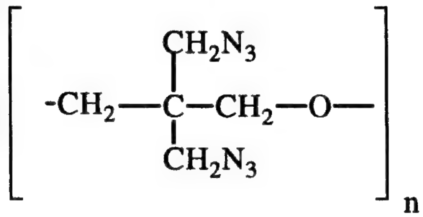
1. Substance or Composition: Bis(2-methylaziridinyl) 2-(2-hydroxypropanoxy) propylamino phosphine oxide	**3. Molecular Structure:** Unknown
2. CAS Registry No.: Not registered	
4. Acronym(s) or Trade Designation(s): BOBBA 8	
5. Synonyms:	
6. Chemical Composition: Unknown	
7. Control Status: Controlled by ML-8 Note 2	
8. Quality: Not specified	
9 Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: None	
14. Production Capacity: None	**15. Cost:** Not applicable
16. Shipping Pack & Label: Unknown	
17. Color & Form: Unknown	
18. Foreign Producers: U.K.	
19. Foreign Capacities: Unknown	

20.	**Military Uses:** Bonding agent for missile propellants
21.	**Civil Uses:** None
22.	**Notes:** BOBBA 8 is a derivative of MAPO used in the UK; the source of the MAPO used has not been identified. The acronym BOBBA 8 is UK usage that stands for "Bob's Bonding Agent No. 8".
23.	**References/MILSPECS:**

1. Substance or Composition:
Bis(azidomethyl)oxetane

2. CAS Registry No.:
17607-20-4

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
BAMO

5. Synonyms:
2,2-bisazidomethyl-4-oxacyclobutane;
3,3-bis(azidomethyl)oxetane

6. Chemical Composition:
$C_5H_{10}N_6O$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12.

8. Quality:
Not specified

9. Precursors:
Bischloromethyloxetane
Sodium azide

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Alliant Hercules?

14. Production Capacity:
Developmental quantities.

15. Cost:
>$2.00 per gram

16. Shipping Pack & Label:
Not available

17. Color & Form:
Not available

18. Foreign Producers:
Japan, Japanese Defense Agency (Asahi Chemical Industry Co., Oita; Daicel Chemical Industries Ltd.) UK (ICI)

19. Foreign Capacities:
Developmental quantities.

20. Military Uses:
Experimental energetic binder for missile propellants.

21. Civil Uses:
None.

22. Notes:
It has been known since the 1950s that 3,3 bis(chloromethyloxetane (BCMO) was polymerizable. BAMO has been shown to be the most polymerizable of the energetic derivatives of BCMO, but is not known explicitly to be available outside NATO, and the cost of the sodium azide used in its synthesis is a factor limiting its application in propellants and high explosives.

The Japanese Defense Agency is evaluating BAMO, as part of their search for energetic binder materials. A published study was concerned primarily with HMX/BAMO (Ref. 1).

The UK (ERDE, Waltham Abbey) is also following the developments, using N_2O_5 for nitration of BCMO, for example. Japan (Daicel Chemical Industries, Ltd.) is also believed to manufacture BCMO, which it uses in commercial co-polymers, and thus has the awareness and the potential to make BAMO, etc., even if it does not already do so (Ref. 2). In collaboration with the Asahi Chemical Industry Co., the Japan Defense Agency, Tokyo is also studying poly-BAMO/NMMO copolymers (Ref. 3).

23. References/MILSPECS:

1. Oyumi, Y., K. Inokami, K. Yamazaki, and K. Matsumoto, *Propellants, Explos., Pyrotech.* 1993, 18, 62.
2. D. Debenham, W. H. Leeming, E. J. Marshall. *Proceedings of 21st. International Conference of Fraunhofer Institute of Chemical Technologie*, Karlsruhe, Germany 1990, p. 53-1.
3. Eishu Kimura, Yoshio Oyumi, Hideo Kawasaki, et al., *Propellants, Explos., Pyrotech.* 1994, 19, 270.

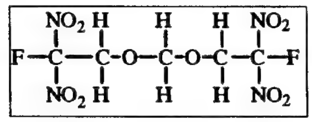
1. Substance or Composition: Bis(chloromethyloxetane)	**3. Molecular Structure:** Unknown
2. CAS Registry No.: 142173-26-0	
4. Acronym(s) or Trade Designation(s): BCMO	
5. Synonyms: 2,2-bischloromethyl-4-oxacyclobutane 3,3-bis(chloromethyloxetane)	
6. Chemical Composition: $C_5H_8OCl_2$	
7. Control Status: Controlled by ML-8 Note 5; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Unknown	
12. Production Equipment: Unknown	
13. U.S. Producers: Unknown	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label: Not available	
17. Color & Form: Not available	
18. Foreign Producers: Russia	
19. Foreign Capacities: Unknown	

20.	**Military Uses:** A precursor for BAMO, AMMO, BNMO and NMMO, energetic solid propellant and high explosive binders.
21.	**Civil Uses:** Unknown
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition:
Bis-2-fluoro-2,2-dinitroethylformal

2. CAS Registry No.:
17003-79-1

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
FEFO

5. Synonyms:
1,1'-[methylenebis(oxy)]bis[2-fluoro-2,2-dinitroethane];
1,7-difluoro-1,1',7,7'-tetranitro-3,5-dioxaheptane

6. Chemical Composition:
$C_5H_6N_4O_{10}F_2$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9 Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:

14. Production Capacity:
Limited

15. Cost:
Not available

16. Shipping Pack & Label:
Class 6.1 , toxic substance; Class 1.1 explosive.

17. Color & Form:
Straw colored liquid

18. Foreign Producers:
Russia; China

19. Foreign Capacities:
Unknown

20.	**Military Uses:** Ingredient of polymer-bonded high explosive and propellant compositions
21.	**Civil Uses:**
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition: Boron	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: 7440-42-8	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:

6. Chemical Composition:
B

7. Control Status:
a. Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR
b. Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR
c. Controlled by MTCR

8. Quality:
a. 85% or higher purity; average particle size of 5 micrometers or less (ML, USML);
b. Powders in particle sizes <60 micrometres whether spherical, atomized, spheroidal, flaked, [sponge], or ground (ML, USML
c. Particle sizes <500 micrometers, whether spherical, atomized, spheroidal, flaked , or ground consisting of 97% by weight or more of B (MTCR)

9. Precursors:
b. Boron stock

10. Precursor Quality:
b. 99% or greater purity

11. Production Process:
Reduction of boron oxides, borates, or boron halides.

12. Production Equipment:

13. U.S. Producers:
Eagle-Picher; Callery Chemical Co., Callery PA; Kerr McGee, Oklahoma City, OK; SB Chemicals; ESK (U.S. subsidiary), New Canaan, CT

14. Production Capacity: Unknown	**15. Cost:** a. $20-40 to $200-400 per lb, depending on purity and fineness of particle size

16. Shipping Pack & Label:
No UN Class assigned

17. Color & Form:
Brown powder

18. Foreign Producers:
H.C. Stark Co., Germany; Elektroschmelze Werk Kempten (ESK) GmbH, Germany

19. Foreign Capacities:
Significant

20. Military Uses:
Ducted rockets.

21. Civil Uses:
In metal industries as a de-oxidizer and degasifier and to increase the hardness of steels; nuclear reactor control rods. Used to manufacture boron alloys (carbides, borides, silicides, etc)

22. Notes:
Control limits for B and B_4C were set to avoid covering lower quality grades that are used as refractory materials and constituents of grinding mixes. The control level was raised to 60μ, although it was subsequently recommended that controls be restored at the 5μ level. The purity (elemental, not isotopic) normally used for air breathing, ducted motors is about 90–95%, and 85% overlaps with materials (particularly B_4C) that have other, civil industrial applications. An 85–95% level is close to that for the grades covered by MIL B-51092 (ORD), but the particle size of 5μm is somewhat larger than the MIL SPEC requirement. Purer material (98–99%) is available in lumps of 1–15 mm size, but such sizes are not suitable for rocket fuels.

Germany is perhaps the principal source of the materials for missile applications, e.g., from H.C. Stark Co. or Elektroschmelzwerk Kempten (ESK) GmbH. The latter has a registered subsidiary in New Canaan, Connecticut. The Callery Chemical Co. may now manufacture the Stark product in the U.S. under license. Eagle-Pitcher, Norton Co., Kerr McGee and SB Chemicals are other potential U.S. sources of supply, but some of these are possibly outlets for the German products.

The intent is to cover "natural" boron and not to control B-10 enriched material. Purity combined with fine particle size and lot size are as significant cost factors in determining the cost of the boron products. It is unlikely, but not impossible, that a determined nation would purchase enriched material for the development of experimental rocket motors, but it would then be faced with the difficult choice of continuing into production with a very expensive fuel, or re-optimizing its prototype to accommodate the significantly different physical and chemical properties of the more abundant natural materials.

Boron is among the most common fuels used for the development of ducted rockets. Ducted rockets depend on the combustion of a fuel-rich gas, generated in a primary combustor, with the ram-air induced from the atmosphere in a secondary combustor. Performance is very much dependent on mixing. The fuel-rich gas is produced with AP/PB; AP/CTPB; NC/NG; GAP; and B, Al, Mg, Ti, or Zr particles may all be used as fuel components. Boron is very effective and the parameters determining its efficiency have been studied at least since 1970 (Ref. 1) . However, boron does not totally oxidize easily because of oxide formation on the burning surfaces of particles. Since that time several countries have maintained active programs to develop the technology.

For example, in Japan AP (50–30%) is mixed with B(20–40%), making up a total of about 70% with 30% CTPB. The theoretical fuel specific impulse, Isp, of AP/CTPB/B propellants range from 500 to 1400s as the air:fuel ratio increases from 5 to 25 (Ref. 2). Or better, Japan has substituted GAP for the CTPB (Ref. 3). The former study showed that the combustion efficiency increases very markedly as boron particle sizes decrease and is relatively independent of the fuel:air ratio; combustion is very difficult when the particles are >9μm, but is good at 2–3μm. **(Cont.)**

22. Notes (Cont.):

Boron combustion and oxide formation in a slurry have also been studied in Germany using 96% boron of 1µm size with AP GAP, energetic plasticizers and Fe_2O_3 (Ref. 4). Continuing studies of boron particle combustion are found in Taiwan (Chung Shan Institute) (Ref. 5) and Israel. It is unlikely that the specific topics have been ignored in the FSU; the combustion of Mg and boron was published in the open literature (Ref. 6). Quality boron is presumably available to them from their nuclear programs, and they may have used boron in their solid propellants. Similar comments could made about China and India.

It is necessary to determine whether the coarse (>60 - <500µm) grade of boron needs to be listed, except as a precursor for the finer grades covered by the USML and ML.

23. References/MILSPECS:

1. Schadow, K., Combustion Sci. Techn. 1972, 5, 107–117.
2. Kubota, N., K. Miyata, T. Kuwahara, M. Mitsuno, and I. Nakagawa, Propellants, Explos., Pyrotech. 1992, 17, 298–302.
3. Kubota, N., and T. Kuwahara, Propellants, Explos., Pyrotech. 1991, 16, 51–54.
4. Eisenreich, N., H. H. Krause, A. Pfeil, and K. Menke, Propellants, Explos., Pyrotech. 1992, 17, 161–163.
5. Liu, T.-K., S.-P. Luh, and H.-C. Perng, Propellants, Explos., Pyrotech. 1991, 16, 156–166.
6. Kharatyan, S. L., G .A. Nersisyan, K. G. Alkhazyan, V. D. Gladun, and D. Z. Safaneyev, 1986, 4,
7. MIL B-51092 (ORD).

1. Substance or Composition: Boron Carbide **2. CAS Registry No.:** 12069-32-8 **4. Acronym(s) or Trade Designation(s):** Tetrabor; Norbide	**3. Molecular Structure:** Not applicable
5. Synonyms: None	
6. Chemical Composition: B_4C	
7. Control Status: Controlled by ML-8 Note 1a	
8. Quality: 85% or higher purity; average particle size of 5 micrometres or less	
9. Precursors: Boron powder	
10. Precursor Quality: Not specified	
11. Production Process: Not specified	
12. Production Equipment: Not specified	
13. U.S. Producers: Norton Co. Worcester, MA	
14. Production Capacity: Unknown	**15. Cost:** $40-80 to $400-800 per lb, depending on purity and fineness of particle size
16. Shipping Pack & Label: No UN Hazard Class assigned	
17. Color & Form: Dark gray powder	
18. Foreign Producers: H.C. Stark Co., Germany; Elektroschmelze Werk Kempten (ESK) GmbH, Germany	
19. Foreign Capacities: Significant	

20.	**Military Uses:** Ducted rockets
21.	**Civil Uses:** Industrial grinding powders
22.	**Notes:** See Notes for boron. Norton Co.'s Norbide products are believed to identical with ESK Tetrabor.
23.	**References/MILSPECS:**

1. Substance or Composition: Butacene	**3. Molecular Structure:** Unknown
2. CAS Registry No.: 125856-62-4	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms: An adducted polymeric ferrocene derivative; Ferro-adduct on HTPB R45M	
6. Chemical Composition: Not available	
7. Control Status: Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Not specified	
12. Production Equipment: Not specified	
13. U.S. Producers: Unknown	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label: Not available	
17. Color & Form: Liquid	
18. Foreign Producers: Germany?	
19. Foreign Capacities: Unknown	

20. Military Uses: Propellant guide	
21. Civil Uses: Unknown	
22. Notes:	
23. References/MILSPECS:	

1. Substance or Composition: Butadiene-nitrileoxide	**3. Molecular Structure:** Unknown
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s): BNO	

5. Synonyms:
Diol-terminated CTPBAN, a copolymer of CTPB (qv) with acrylonitrile, with acrylonitrile:butadiene ratios above 15% (usually 25%)

6. Chemical Composition:
C_4H_9NO

7. Control Status:
Controlled by ML-8 Note 2

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Unknown

14. Production Capacity: Not available	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 1.3 explosive

17. Color & Form:

18. Foreign Producers:
Unknown

19. Foreign Capacities:
Unknown

20. Military Uses:
No longer of current military interest

21.	**Civil Uses:** Unknown
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition:
Butanetriol trinitrate

2. CAS Registry No.:
6659-60-5

3. Molecular Structure:

$CH_2(ONO_2)\ CH_2\ CH(ONO_2)\ CH_2(ONO_2)$

4. Acronym(s) or Trade Designation(s):
BTTN

5. Synonyms:
1,2,4-butanetriol trinitrate

6. Chemical Composition:
$C_4H_7N_3O_9$

7. Control Status:
Controlled by ML-8 Note 2.c USML CAT V §121.12 b(3); MTCR

8. Quality:
Not specified (but it is the acid-free grade that is required)

9. Precursors:
Butane triol

10. Precursor Quality:
Not specified

11. Production Process:
Nitration of butane triol with mixed acids.

12. Production Equipment:
Biazzi nitroglycerin plant or similar.

13. U.S. Producers:
Unknown

14. Production Capacity:
Unknown

15. Cost:
Not available

16. Shipping Pack & Label:
UN Class 3, flammable liquid

17. Color & Form:
Light yellow liquid

18. Foreign Producers:
Germany; see notes

19. Foreign Capacities:
Unknown

20. Military Uses:
A substitute plasticizer for some of the expensive TVOPA used with acrylate/acrylic propellant binders

21. Civil Uses:
Unknown

22. Notes:
BTTN, like MTN, is used as an additive to polymeric binders in missile and rocket propellants. It was used by Germany in World War II as a gelatinizer for nitrocellulose in the same way as NG (nitroglycerin) may be applied. In fact, the preparation and properties of BTTN overall are very similar to those of NG, and the explosive properties were presented in the open literature in 1940. Any country with Biazzi NG plants can manufacture BTTN in quantity.
A very high quality, acid-free BTTN is, however, required for its use in modern stockpiled or strategic propellants. Without this quality, gassing occurs and compositions have poor shelf-life. The U.S. and NATO allies are the only known or potential sources of the manufacturing technology for the high quality product, and the United States is the only known actual producer, and is the basis for retention of controls on the export of BTTN and its precursor.

23. References/MILSPECS:

1. Substance or Composition: Carboxylterminated polybutadiene	**3. Molecular Structure:** See composition
2. CAS Registry No.: 68441-48-5	
4. Acronym(s) or Trade Designation(s): CTPB; Butarez-CTL	
5. Synonyms:	
6. Chemical Composition: $(C_4H_6)_x$	
7. Control Status: Controlled by MTCR (CAT 1.C.b.1)	
8. Quality: MILSPEC: Non-functional Type I (low acid); Type II (high acid)	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Solperene (sulfur-finished) process	
12. Production Equipment: Not specified	
13. U.S. Producers: Philips Petroleum Co. Bartlesville, OK. Tel: 918 661-5178. John Roberts	
14. Production Capacity: 500,000 lb per year	**15. Cost:** Not available
16. Shipping Pack & Label: Not available	
17. Color & Form: Liquid. Color: Type I, Gardner 9; Type II, Gardner 8	
18. Foreign Producers: Philips process licensed to Repsol Quimica, Spain; Japan Elastomer Co.; Novum, Mexico.	

19. Foreign Capacities:
Unknown

20. Military Uses:
95-99% used for missile propellants within NATO community

21. Civil Uses:
1-5% commercial developments, not in production

22. Notes:
International Institute of Synthetic Rubber Producers, 2077 S. Gessner Road., Suite 133, Houston TX 77063. Tel; (713) 783-7511. Bill Tessner, President, has helpful info. on world-wide availability of synthetic rubbers.

CTPB was listed in MCTL Section 20.2 in 1986, but dropped from the 1989 edition because of Warsaw Pact capability, both for its own systems and for systems exported, for example, to Egypt. It continues to be listed in the MTCR.

CTPB cured with epoxides or aziridines represents old technology dating back to the 1960s that continues to be used in the U.S. (and elsewhere) only because of the prohibitive cost of developing and requalifying systems with propellant formulations based on HTPB or other more energetic binder/fuels. The use of CTPB in rocket propellants was used by the former Warsaw Pact countries almost as long as by NATO. FSU technology is believed focused on a general purpose product and to lag in the production of specialty products.

CTPB is used in the space shuttle liner and for the second and third stages of the Minuteman in quantities up to 80,000 pounds per year each. It is also used for the Standard Missile liner to the extent of about 6000 lb/year. It was used in the Sparrow missile, but this is no longer produced. CTPB has not been used in Army missiles for at least 15 years. A comment from the Aerojet program manager indicated that CTPB is difficult to obtain in adequate quantities.

There is only one significant manufacturer of CTPB liquid in the U.S., and only a military grade 95–99% of production is used for military purposes within NATO. The remaining 1–5% of U.S. capacity is used for commercial developments, none of which are known to have gone into production. Phillips uses its proprietary Solperene (sulfur-finished) process for the manufacture of CTPB, and this is reported to have been licensed to Spain (Repsol Quimica), Japan Elastomer Co., and Mexico (Novum). The Mexican plant was reported to have been 39% owned by Phillips before being sold to Novum in the 1970s. A company in Hong Kong was also licensed to use the process, although this is reported to be out of business.

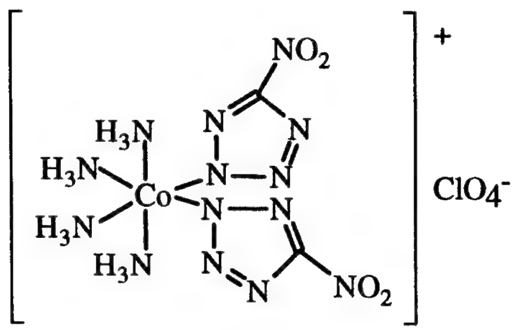
Nippon Soda (Japan) sells a product known as Nisso-PB-C100, which is reported to be a peroxide-finished CTPB manufactured by a different process. Blended with styrene, it gives tough, abrasion-resistant qualities and is used for making golf balls. It has been described as a "cheap way to get a loud click" when the ball is struck, and has resulted in substantial imports into the U.S. from Taiwan and Japan, possibly through the Sumitino-Dunlop companies. Phillips considers this to be a different product than their CTPB, having for example a vinyl content of greater than 85–90 percent, a functionality greater than 1.6, specific gravity 0.89, and viscosity 50–250 poise (5–25 mPa.sec) at 45° C (113° F).

23. References/MILSPECS:
MIL-P-23942

1. Substance or Composition:
Cis-bis(5-nitrotetrazolato)tetra amminecobalt(III) perchlorate

2. CAS Registry No.:
Not registered

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
BNCP

5. Synonyms:
Tetraammine bis(5-nitro-2H-tetrazolato-N^2)cobalt(III) perchlorate

6. Chemical Composition:
$(H_{12}N_{14}O_8)ClCo$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Sodium 5-nitrotetrazolate dihydrate = $NaTzNO_2.2H_2O$; and CTCN = tetraamminecarbonatecobalt(III) nitrate

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Pacific Scientific Inc.,
Energy Dynamics Div.
7073 West Willis Drive, Box 5002
Chandler AZ 85226-5111
Contact: Mr John Fronabarger
Tel: (602) 796-1100

14. Production Capacity: Kilogram lots	**15. Cost:** About $50.00/gram ($22,800/lb)
16. Shipping Pack & Label: Class 1.1 explosive	
17. Color & Form: Golden orange crystals	
18. Foreign Producers: None known	
19. Foreign Capacities: Unknown	
20. Military Uses: Initiating agent in detonators and actuator cartridges for nuclear and missile warheads.	
21. Civil Uses: None	
22. Notes: BNCP is listed in the USML V and ML 8 because of its potential for nuclear weapons and ICBM applications. It is sufficiently powerful and easily detonated that it permits designers to avoid the use of lead azide and PETN combinations for the initiation of HMX by either laser or hot-wire techniques. It requires less than 20 mg to be effective in detonators, but is not as stable as CP. It has apparently been neither exploited nor even prepared in any NATO country; but may have been made in CH and/or FSU.	
23. References/MILSPECS:	

1. Substance or Composition: Compounds composed of fluorine and one or more of the following: other halogens, oxygen, or nitrogen	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: Not registrable	
4. Acronym(s) or Trade Designation(s): Not applicable	
5. Synonyms: b. Compounds composed only of fluorine and halogens, oxygen, or nitrogen	
6. Chemical Composition: Not applicable; various	
7. Control Status: a. Controlled by ML-8 Note 1a.; USML Cat V §121.12; MTCR b. Controlled by USML CAT V §121.14	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Not specified	
12. Production Equipment: Not specified	
13. U.S. Producers: Fluochem, and others	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label:	
17. Color & Form: See notes	
18. Foreign Producers: FSU	
19. Foreign Capacities: Unknown	

20. Military Uses:
Oxidizers for missile propellants.

21. Civil Uses:
Unknown

22. Notes:
The MTCR lists this general class of substances under the heading "liquid oxidizers," a reflection of their current practical interest. It has been listed in ML 8 for over thirty years; it has also been listed under that or equivalent subsections of the MCTL since its inception. In the USML it is listed as in the ML.

Better internal consistency would result if the separate listing of liquid oxidizers were removed. At normal temperatures and pressures most of the relevant substances are gases rather than liquids, and other characteristics make them compatible with that arrangement. (e.g. ClF, ClF_2, ClF_3 are colorless gases) Nevertheless, as employed for missile technology the substances are liquified. The only specific substance of this class proposed for inclusion in ML 8 was oxygen difluoride; this is covered by the general statement 'oxyfluorides', and by the same statement in the MTCR. Since there are probably even more impediments to the transportation and commercialization of the substance than the oxides of nitrogen, a separate entry is not necessary.

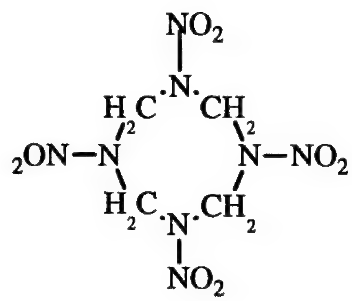
Among other related substances, chlorine trifluoride is listed in ML 8, Note 7, entry kk, because it is a commercial substance listed in the Core List. If it is deleted from the Core List in the future, it will, as in the past, still be covered by the general entry unless specifically excepted.

Chlorine pentafluoride (ClF_5) is also covered by the generalities of the 'liquid oxidizer' coverage. Similar comments apply to this substance as are given above for oxyfluoride.

23. References/MILSPECS:

1. Substance or Composition: Cyanoethylated polyamine salts	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: Not registrable	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms: Salts of cyanoethylated polyamine, derivatives of TEPAN (qv)	
6. Chemical Composition: Various	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: TEPAN	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: 3M Company, Specialty Chemicals Div., 3M Center, 236-2A-01, St. Paul MN 55144-1000. Tel: 612 458-1392; FAX: (612) 458-1383. Dr. Anthony P. Manzara	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label: Not determined	
17. Color & Form: Not determined	
18. Foreign Producers: Unknown	

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Missile propellant ingredient
21.	**Civil Uses:** None
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition: Cyclotetramethylene-tetranitramine	**3. Molecular Structure:** 
2. CAS Registry No.: 2691-41-0	
4. Acronym(s) or Trade Designation(s): HMX [= High Melting Explosive]; octogen; octogène	

5. Synonyms:
Tetramethylenetetranitramine;
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine;
1,3,5,7-tetranitro-1,3,5,7-tetrazacyclooctane;
1,3,5,7-tetranitro-octahydro-1,3,5,7-tetrazocine;
1,3,5,7-tetraza-1,3,5,7-tetranitrocyclooctane

6. Chemical Composition:
$C_4H_8N_8O_8$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT Y §121.12; MTCR; NDUL 6.4

8. Quality:
Not specified

9. Precursors:
1,3,5,7 tetraacetyl-1,3,5,7-tetraaza-cyclooctane
Acetic anhydride
Nitric acid

10. Precursor Quality:
Not specified

11. Production Process:
Currently, the most important new process is the TAT or GARDEC process for manufacturing HMX (an analogous TRAT process may also be used to prepare RDX). The synthesis by this route has been described in the literature, and proceeds via the production first of a precursor, 1,3,5,7-tetraacetyl-1,3,5,7-tetraazacyclooctane (or TAT). This is then nitrated with nitric acid, or nitric acid-nitrogen pentoxide, to HMX. Elements of the process are classified. The importance of the process is that it promises to be significantly cheaper than the DADN process, and may be able to draw on elements of the DADN process to enhance its attractiveness. Furthermore, the product is reported to be of higher purity than either the Holston process or the DADN process, with a potential for marginally improved performance when used in formulations that depend on HMX for their superiority. Currently, the process is in the pilot plant stage of development at ARDEC, producing both TAT and HMX. (see also Notes)

12. Production Equipment:
Nitration equipment

13. U.S. Producers:
Holston AAP, TN

14. Production Capacity:
3,200,000-10,000,000 lb/yr.

15. Cost:
About $22.00/lb, but has varied from $1.00 to $25.00/lb depending on demand and pollution abatement and energy costs.

16. Shipping Pack & Label:
UN Hazard Class 1.1D. Generally, packed in 55 gal. drums, in water (not <15% by weight), a phlegmatizer (not <10% by weight), or water-alcohol mixtures(not<15% by weight). When containing less than the specified amounts of desensitizer should not be transported without approval of a competent authority.

17. Color & Form:
White, or colorless crystals.

18. Foreign Producers:
Chugok Kayaku, Japan; Dyno Industrier, Norway; PRB Belgium, by reprocessing RDX, Bridgewater Ordnance plant, UK; F. N. Valladolid, Rio Tinto, Spain(?); Pravisani, Colleferro, Italy; China; FSU; Somerchem PTY, South Africa(?)

19. Foreign Capacities:
Generally, up to 6-9 metric tonnes per day.

20. Military Uses:
Important ingredient of solid rocket propellants and the most powerful high explosive warheads; also used in nuclear munitions

21. Civil Uses:
Use in oil well stimulators requiring lifetimes of 200 hr @ up to 300°F

22. Notes:

Respectively, homologous 6- and 8-membered ring compounds, RDX and HMX are important because they are the two most powerful high explosives commonly used in conventional and nuclear munitions at the present time. They are also high energy ingredients in missile propellants and are used in high energy gun propellants that have been under development in several NATO countries.

They are listed in the USML and ML because of their importance for nonproliferation concerns, although production capabilities, of limited capacity, efficiency and product quality exist in 15–20 countries worldwide, as discussed below. Detailed descriptions of processes for making HMX were given (Ref. 1) together with process flow diagrams, etc. These summarize capabilities that, at least to some degree, are to be found worldwide.

The 1990 MCTL lists both continuous processes, and new, non-Bachmann type, batch processes that are only now being introduced into the U.S./NATO production base.

HMX is produced in Japan (Chugok Kayaku), Norway (Dyno Industries), and Belgium (PRB) by processing their RDX; and by the UK (Bridgewater) by direct synthesis. The Japanese product is cheaper than the U.S. product. Physics International is also reported to import cheap HMX/TNT (Octol) from Dyno Industrier, Norway, for use in munitions loading in the U.S. Army Ammunition Plant at Ravenna. A paper from Spain on the effects of RDX on the behavior of HMX may indicate the fulfillment of a Spanish objective to produce HMX. The company involved is believed to have agreements with Argentina for the development of munitions. Up to about 1988 Spain had no capability to manufacture HMX, except on the laboratory scale, but was believed to be investigating either or both of the DADN and TAT processes. However, it was reported that F. N. Valladolid, Rio Tinto, was working with the Italian Pravisani Company to construct a Bachmann-type nitramine facility at Rio Tinto, similar to a facility under development at Colleferro, Rome.

During the 1970s that the FSU sought information on the U.S. Bachmann process for manufacturing HMX by obtaining copies of the environmental impact statements that are on file in the public library in Kingsport, TN. From these statements it is possible to acquire significant data about the quantities of reactants, reaction times, reaction yields, and other details about the process. It is not known whether this information was sought in order to correct problems with FSU processes or products, or to implement Soviet policy to minimize environmental pollution in the neighborhood of their facilities.

The FSU and other former Warsaw Pact countries are otherwise known to have sought alternative or improved processes to increase the yield, quality, or cost and energy efficiency of their HMX plants. There is no evidence that they have introduced continuous processes, or processes other than the old K- or KA-processes for RDX and HMX.

The FSU increased its production capacity for HMX in recent years and now has a large production base that is probably more than sufficient for its internal peacetime needs.

There is a growing capability among other non-NATO countries to manufacture the nitramines. The emphasis of this trend has been directed toward the production of the cheaper, less powerful RDX. Both UK and U.S. technology have been drawn on as sources for the development; the tendency now is for Bachmann-type processes to be introduced. In the future, therefore, a potential for, if not the actual, increased production of HMX will exist in the non-NATO countries. **(Cont.)**

22. Notes (Cont.):

In assessing the significance of the availability of the Bachmann (or Woolwich) technology in any country, it is important to realize that even if used ostensibly for RDX production, the process can be pushed to yield a product that has up to 30 percent HMX content, and this can then be separated as relatively pure HMX. Moreover, most of U.S.-type formulations that use HMX as an ingredient can equally be produced with RDX as a substitute as long as the country is willing to accept a small loss of performance along with an increase in munition survivability.

Among non-NATO countries that provide "turnkey plants" for the batch or continuous production of RDX and HMX are Sweden (Nitro-Nobel, Nobel Chematur) and Switzerland (Biazzi). South Africa has the technical competence to do so. Within NATO, private industry also provides design services and equipment, some of which is overtly advertised for the development and supply of HMX plants (e.g., Joseph Meissner, GmbH., Cologne, GE).

Bofors (Nobel Chematur) is believed to have installed a "turnkey plant" for the manufacture of RDX in Brazil by the Bachmann process. This implies that Brazil may also have the ability to manufacture HMX. The quality of the product is not known, but it is reported to have been imported into the U.S. from Brazil by a U.S. broker for oil well perforation purposes (although Holston AAP produces only at reduced capacity, non-military users find it difficult to obtain RDX or HMX in the U.S.).

CH manufactures HMX; it not only follows the NATO literature to improve the HMX processes, but undertakes pioneering research to synthesize denser, powerful explosives within the nitramine field. The plants are reported to be significantly more labor-intensive than their U.S./NATO equivalents.

Israel can make some HMX, but it imports octol (70 percent HMX) for its shaped-charge warheads. South Africa, in its government-owned, contract-operated plant at Somchem Pty, Somerset West, RSA, manufactures TNT, RDX (only) and tetryl. It is considering HMX and HNS for use in projectiles.

Military explosives are manufactured in South Korea primarily by the Korea Explosives, Ltd., many of whose personnel have been trained by U.S. Army personnel. Several U.S. personnel have spent 3–6 months in Korea giving courses of instruction, and at least 10–20 Korean personnel have received 60–90 days training at U.S. Army installations. Korea Explosives, Ltd., manufactures nitroglycerin, nitrocellulose, TNT and RDX (HMX is considered very expensive, and presumably is not made in quantity). Sweden has been involved with the development and manufacture of high explosives, propellants, and pyrotechnics since their discovery in the mid 19th century and successful application for military and domestic (mining, civil engineering, etc.) purposes. Throughout the 20th century, Sweden has continued to keep abreast, and in some instances, pioneer the exploitation, if not the discovery, of new explosives. Nobel Chematur is fully capable of producing HMX to meet Sweden's internal needs, or to export these substances if required. Total production capacities for these substances are not known, but Bofors are believed to be working on a continuous process to produce 9 metric tonnes per day (594,000 lb/month).

Singapore, Indonesia, and Taiwan also all have batch processes for RDX, but as yet no HMX capabilities. SNPE (France) was reported in the late 1980s to be ready to construct a new plant about 120 km from Bandung.

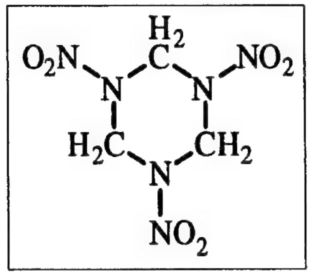
23. References/MILSPECS:

1. Walker, R. F., and N. D. Jorstad, "*Energetic Materials and Devices Technology Guide and Foreign Technology Assessment*," Institute for Defense Analyses, Alexandria, VA, 1990.
2. MIL-H-45444B

1. Substance or Composition:
Cyclotrimethylenetrinitramine

2. CAS Registry No.:
121-82-4

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
RDX [= Research Department Explosive];
Cyclonite; T4; Hexogen; Hexogène

5. Synonyms:
Hexahydro-1,3,5-trinitro-1,3,5-triazine; or
1,3,5-trinitro-1,3,5-triazacyclohexane; or
1,3,5-trinitrazacyclohexane

6. Chemical Composition:
$C_3H_6N_6O_6$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR; NDUL 6.4

8. Quality:
None specified; marketed in various grades based on particle size.

9. Precursors:
Hexamine, nitric and acetic acids, acetic anhydride

10. Precursor Quality:
None specified

11. Production Process:
Bachman process; Woolwich process; see notes for new processes under development

12. Production Equipment:
See, under Notes, a discussion of the Holston Process

13. U.S. Producers:
Holston AAP, TN; acetic anhydride furnished by Tennessee Eastman Co., Kingsport, TN

14. Production Capacity:
Over 32,000,000 pounds (over 14,500 metric tonnes) per year. During WWII up to 1,000,000 lb/day.

15. Cost:
$8.00-12.00 per lb.

16. Shipping Pack & Label:
55 gal drums containing crystalline powder in water or water-alcohol mixtures; UN Class 1.1 explosive.

17. Color & Form:
White or colorless crystals.

18. Foreign Producers:
In seventeen foreign countries.

19. Foreign Capacities:
See discussion under Notes.

20. Military Uses:
High explosive warheads; mines and demolition explosives; booster explosives; gun, missile, and rocket propellants. Use in gun propellants is largely experimental.

21. Civil Uses:
Oil well penetrators.

22. Notes:
Widespread knowledge of the manufacturing processes, and the proliferation of production plants throughout the world, led to the listing of only continuous or "new" processes for these substances as critical technologies. New processes are non-Bachmann or non-Woolwich processes for RDX manufacture, as discussed for HMX (qv).

A continuous process for RDX was installed in the UK (Bridgewater) in about 1977. U.S. and Belgium (P.R.B., Balen) are also developing continuous processes. The latter has innovative instruments and controls and auto-recrystallization of the RDX, requiring only one man versus the four used in the U.S.

Within NATO batch processes for the manufacture of RDX also operate in Norway (Dyno Industrier uses both the Woolwich and Bachmann processes), Italy (Colleferro), France (SNPE, Sorgues uses the Woolwich process), Japan (Chugok Kayaku uses the Bachmann, Nippon Kohki uses the old German process), and Belgium (P.R.B. also has a Bachmann operation).

It has been reported that in Spain, F. N. Valladolid, Rio Tinto, has worked with the Italian Pravisani Company to construct a Bachmann-type nitramine facility at Rio Tinto, similar to a facility now under development at Colleferro, Rome. The latter has a capacity of 6 metric tonnes per day of RDX.

Recognition of the potential of RDX followed the issue of a German patent in 1920. Prior to World War II, Germany, Italy, UK, France, Canada, and U.S. all investigated its preparation, but exploitation was hindered by the low yields and high cost of the products. Economically-acceptable processes were developed in the UK and Canada, and then in the U.S. during World War II, but total production was limited in some countries. The UK, for example, produced only 19,200 tons at Bridgewater during that period.

RDX is usually produced by the nitration of hexamine (hexamethylene tetramine) with concentrated nitric acid, and precipitation of the product in ice water. This is known as the Woolwich (or Schurr-Henning) process and represents the continued development of Henning's approach of 1898. The scale-up to an industrial scale was made possible by the use of highly concentrated acid to
(Cont.)

22. Notes (Cont.):

improve the yield and by careful control of the reaction temperature to retain adequate safety. The reaction product is filtered from the spent acid, recrystallized to achieve the desired levels of purity, and milled to produce a range of particle sizes.

In the old German (or Knöffler) process, ammonium nitrate is added to the mixture, followed by warming. An increased yield results because formaldehyde is split off from the hexamine molecule and is also used to form RDX.

The Bachmann process (in Germany, the Knöffler-Appel or KA-process) reacts hexamine, ammonium nitrate and nitric acid in an acetic anhydride medium. RDX may also be formed through the reaction or addition of paraformaldehyde. Waste acetic acid is formed, and this is concentrated and recycled to regenerate acetic anhydride.

The Holston Army Ammunition Plant (HAAP), operated since 1943 at Holston, TN, is the only U.S. plant that manufactures RDX (and HMX) by the Bachmann process. Another plant in Ohio used the Woolwich process, but this no longer exists. Although closed following World War II, HAAP was reactivated during the Korean conflict with ten production lines capable of producing RDX in various grades by a batch process. The plant has continued to operate at various production levels since that time, although most recently only one or two of the lines are used, and production rates typically have been no more than a third or half of capacity. Nevertheless, it is estimated that currently 90-95% of all NATO RDX is made at Holston.

The Bachmann process requires an abundant supply of acetic anhydride. The Tennessee Eastman Company, which operates HAAP through its subsidiary the Holston Development Corporation, as the contractor for the U.S. Army, manufactures acetic anhydride by a proprietary process at its Kingsport plant and pipes it to the more remote HAAP for several miles alongside the Holston River. Various improvements to the process have been made in recent years, among them, a reduction in the proportion of the acetic anhydride required for the process. See under the Notes for HMX a discussion of alternative processes that are being developed to manufacture RDX without the heavy dependence on acetic anhydride.

In the Bachmann process used at Holston the hexamine (cake) is dissolved in glacial acetic acid, and the ammonium nitrate is mixed with the nitric acid in stainless steel reactors; together with the acetic anhydride there are three concurrent continuous liquid-feeds, regulated to control the temperature of the exothermic reaction in the nitration unit. With efficient mixing, the reaction is complete in about a second.

The three reactants are fed through a centrifugal pump and a long water-jacketed cooling pipes that circulate the reaction mixture back to a tank at the intake of the pump. To minimize the temperature rise at the point of reaction, the feed is diluted with recirculated slurry from the tank in a 50:1 ratio, and the system temperature is maintained at 65°C. Production rates of 50 pounds of RDX/minute are not uncommon in single reactors. Following nitration, the precipitated coarse crystals of RDX are filtered, washed, and dewatered, the output from any line during a given period being further processed for incorporation in various formulations that are produced in bulk. Typically, after the RDX is filtered using a unique belt filter and washed, it is stirred into a water slurry and pumped to another building. The RDX is then recrystallized by dissolving it in acetone or cyclohexanone and reprecipitating it as a water slurry, a process which helps to further purify the product and control the particle size or grade. Other additives and further processing of the slurry may also be introduced to coat the crystals, preliminary to their incorporation in high explosive or propellant formulations. **(Cont.)**

22. Notes (Cont.):

The U.S. is believed to be alone in the world in investigating DMSO for recrystallization, but it is now entering the production stage of development. In 1988 , PRB in Belgium was thought to be ahead of the U.S. in refinement of the cyclohexanone process, but the status of the effort has not been ascertained recently.

The nitration step of the process at Holston can operate continuously; it was unique in the world as of 1986 and permits production from a line at rates up to 4,000,000 pounds per month. However, the overall process is a batch operation. Batches are created by letting the continuous overflow from the reactor vessel accumulate for a set time interval. The batch operation permits the reactor to be fine-tuned for optimum output while isolating it from short-term disruptions downstream. Batch operation is more adaptable for limited production of specialty formulations that are characteristic of peacetime requirements. Batch sizes are about 4500 pounds. Drying the RDX is a major bottleneck in the Holston process. A continuous turbo tray drier modified to make it explosion proof by Wyssmont Co. of Fort Lee, NJ, is critical for modern operations at this stage.

23. References/MILSPECS:

MIL-R-398C

1. Substance or Composition: Decaborane **2. CAS Registry No.:** 17702-41-9 **4. Acronym(s) or Trade Designation(s):**	**3. Molecular Structure:** See composition

5. Synonyms:
Decaboron tetradecahydride
Boron hydride(s)
Boranes in general; one of compounds of generic formulae B_nH_{n+4}

6. Chemical Composition:
$B_{10}H_{14}$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR.

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Callery Chemical Co.,
Route 309,
Mars-Evans City Road,
Callery, PA 16024.
Contact: Ms. Beverly Jones.
Tel: (412) 967 4248
FAX: (412) 967-4270

14. Production Capacity: Limited	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 4.1, flammable solid; secondary risk 6.1, toxic substance.

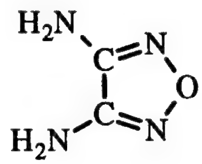
17. Color & Form:
Colorless needles

18. Foreign Producers: Unknown	
19. Foreign Capacities: Unknown	
20. Military Uses: Missile propellants	
21. Civil Uses: None	
22. Notes: It is proposed that the existing boron hydride entries be replaced with entries for specific boranes, such as decaborane.	
23. References/ MIL SPECS:	

1. Substance or Composition:
Diaminofurazan

2. CAS Registry No.:
17220-38-1

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
DAF

5. Synonyms:
3,4-diaminofurazan

6. Chemical Composition:
$C_2H_4N_4O$

7. Control Status:
Not controlled, but of interest

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Unknown

12. Production Equipment:
Unknown

13. U.S. Producers:
Unknown

14. Production Capacity:
Unknown

15. Cost:
Not available

16. Shipping Pack & Label:

17. Color & Form:
Unknown

18. Foreign Producers:
Unknown

19. Foreign Capacities:
Unknown

20.	**Military Uses:** Missile propellant ingredient
21.	**Civil Uses:** None
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition:
Diaminohexanitrobiphenyl

2. CAS Registry No.:
17215-44-0

3. Molecular Structure:

4. Acronym(s) or Trade Designation(s):
DIPAM

5. Synonyms:
2,2',4,4',6,6'-hexanitro-[1,1-biphenyl]-3,3'-diamine;
3,3'-diamino-2,2',4,4',6,6'-hexanitrobiphenyl;
Dipicramide

6. Chemical Composition:
$C_{12}H_6N_8O_{12}$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
None specified

9. Precursors:
See 11 below.

10. Precursor Quality:
Not specified

11. Production Process:
Low temperature addition of dichlorohexanitrobiphenyl to dry ammonia-saturated absolute ethanol.

12. Production Equipment:
Not specified

13. U.S. Producers:
U.S. Navy, NSWC, White Oak MD (Not known to actively produce) (Ref. 1)

14. Production Capacity:
Limited

15. Cost:
>$200 per lb.

16. Shipping Pack & Label:
No UN Hazard Class assigned; but nominally a Class 1.1 explosive.

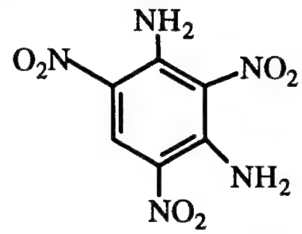
17. Color & Form:
Yellow crystals

18.	**Foreign Producers:** None known
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** A heat-resistant high explosive likely to be used in less sensitive munitions and strategic defense applications in spite of its very high cost.
21.	**Civil Uses:** None
22.	**Notes:**
23.	**References/MILSPECS:** 1. J. C. Dacons, et al. Tetrahedron 19, 797 (1963).

1. Substance or Composition:
Diaminotrinitrobenzene

2. CAS Registry No.:
1630-08-6

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
DATB; DATNB

5. Synonyms:
2,4,6-trinitro-1,3-benzenediamine;
1,3-diamino-2,4,6-trinitrobenzene
2,4,6-trinitro-1,3-diaminobenzol(Ger.)
2,4,6-trinitro-phenylenediamin-(1,3)(Ger.);
2,4,6-trinitrometaphenylenediamine(France)

6. Chemical Composition:
$C_6H_5N_5O_6$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
See production process

10. Precursor Quality:
Not specified

11. Production Process:
Reaction of phosphorous oxytrichloride with dipyridinium styphnate to produce 2,4,6-trinitro-1,3-dichlorobenzene; which is then treated with ammonia.

12. Production Equipment:
Unknown

13. U.S. Producers:
Chemtronics Corp.(no longer in operation)

14. Production Capacity:
None

15. Cost:
Not available

16. Shipping Pack & Label:
Not assigned a UN Hazard Class; nominally Class 1.1

17.	**Color & Form:** Yellow crystals
18.	**Foreign Producers:** Chugok Kayaku, Japan
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Formerly used in US Sparrow missile; now believed used only in UK and Japanese Sparrows made under license.
21.	**Civil Uses:** None; potential oil well perforator explosive
22.	**Notes:** This insensitive high explosive is believed to be made only in the U.S. (Chemtronics) and under license in Japan by the Chugok Kayaku company. DATB has only limited application as a military explosive; as a cheaper substitute for the more powerful, also insensitive, TATB. The U.S. formerly used DATB in the Sparrow missile, although it has since been replaced. It is used by Japan and the UK for their Sparrow missiles, manufactured under license. The Chemtronics plant is no longer operating in the U.S. and in 1986 commented Japan operates their facility in a "superior manner", using only specifications conveyed under license. No other non-NATO manufacturers are known at this time, and nothing is known about the capabilities of other countries to produce DATB.
23.	**References/MILSPECS:**

1. Substance or Composition: Diborane	**3. Molecular Structure:** See composition
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:
Boroethane
Boron hydride(s)
Boranes in general; one compounds of generic formulae B_nH_{n+4}

6. Chemical Composition:
B_2H_6

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR (Boranes)(See notes)

8. Quality:
Not specified

9. Precursors:
Lithium hydride; boron trifluoride

10. Precursor Quality:
Not specified

11. Production Process:
Reaction of boron trifluoride with lithium hydride

12. Production Equipment:
Convection current converters(C^3 reactors)

13. U.S. Producers:
Callery Chemical Co.,
Route 309,
Mars-Evans City Road,
Callery, PA 16024.
Contact: Ms. Beverly Jones.
Tel: (412) 967 4248
FAX: (412) 967-4270

14. Production Capacity: Limited	**15. Cost:** >$200 /lb.

16. Shipping Pack & Label:
UN Hazard Class 2.3, toxic gas; secondarily 2.1, flammable gas

17. Color & Form:
Colorless gas, with a sweet, sickly smell

18.	**Foreign Producers:**
19.	**Foreign Capacities:** No UN Hazard Class assigned
20.	**Military Uses:** Missile propellant ingredient.
21.	**Civil Uses:** None
22.	**Notes:** Specific borane covered by existing borane, boron hydride entries.
23.	**References/MILSPECS:**

1. Substance or Composition: Dicyclopentadienyl iron derivatives **2. CAS Registry No.:** 102-54-5 (the no. for ferrocene, not the derivatives) **4. Acronym(s) or Trade Designation(s):** Ferrocene derivatives	**3. Molecular Structure:** Unknown
5. Synonyms:	
6. Chemical Composition: $Fe(C_5H_5)_2$ with polymer adducts	
7. Control Status: Controlled by ML-8 Note 2.f; USML CAT V §121.12. b5; MTCR	
8. Quality: Not specified	
9. Precursors: Cyclopentadiene sodium; ferrous chloride	
10. Precursor Quality: Not specified	
11. Production Process: Reaction of the two precursors, followed by reaction with other pre-polymeric adducts.	
12. Production Equipment: Unknown	
13. U.S. Producers: Boulder Scientific Co., PO Box 548, Mead CO 80542. Tel: (303) 442-1199; Fax:(303) 535-4584. Contact: Dr. John Birmingham. (See notes)	
14. Production Capacity: 1000 lb./yr.	**15. Cost:** $1000/lb.
16. Shipping Pack & Label: 50 gal. drums.	
17. Color & Form: No Hazard Class; dark liquid.	
18. Foreign Producers: Chemische Betriebe PLUTO, Herne, Germany. (See notes)	

19. Foreign Capacities:

20. Military Uses:
Burn rate modifier and smoke reducer for solid propellants.

21. Civil Uses:
Ferrocene reduces smoke and pollution emissions during the combustion of fuel oils; controls the combustion of pyrotechnics; and is a low cost octane booster for gasoline. Ferrocene is also used as a catalyst during the polymerization of styrene, siloxane, epoxy and phenol resins, and other plastics. It imparts desirable properties to light-degradable films, controls the thermal shrinking of fibers, and is a semiconductor of value for the development of solar power supplies.

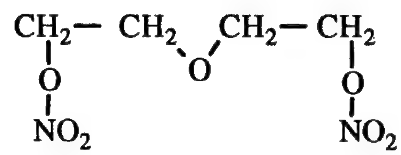
22. Notes:
Ferrocene itself was deleted from the MCTL in 1989 because of the known longstanding FSU interest in ferrocene and of their experimentation with the properties of cyclopentadiene since at least 1945. Being a solid it has not been used in U.S. propellant mixes for thirty years or more because of dispersion-effectiveness problems; other NATO and non-NATO countries have used it in missile propellants since then and some may continue to do so. So-called Hi-Cat-6 was an early U.S. substitute.

It has not been listed in ML-8 at least since 1987, when an editorial change was made during NATO discussions to make it clear that it was not inadvertently covered; it has never been listed in the USML. Liquid or polymeric ferrocene derivatives continue to be listed in both the MCTL and the respective ML and USML control documents. (See comments under Catocene).

Boulder Scientific can make any ferrocene derivative, and now make T-butyl catocene, a second generation replacement for ferrocene.

A French and a FSU capability to produce ferrocene derivatives are believed to exist in addition to the indicated PLUTO capability. SNPE (France) and Bayern Chemie (Germany) experiment with the substances, but it is not known whether small scale production, as opposed to merely laboratory preparations, are involved. Non-NATO countries in general are believed to have no facilities to manufacture the specific substances in quantity. But China is at least one exception because of the wide use of ferrocene and its capability of manufacturing HTPB, CTPB, etc. Laboratory preparation of the derivatives is, however, well within the capability of most developed countries, once the synthetic process is known and the precursors are available. Taiwan was experimenting with catocene at least as early as 1988, but the source of the material is unknown.

23. References/MILSPECS:

1. Substance or Composition: Diethylene glycol dinitrate	**3. Molecular Structure:** 
2. CAS Registry No.: Not determined	
4. Acronym(s) or Trade Designation(s): DEGDN	

5. Synonyms:
Diglycol dinitrate

6. Chemical Composition:
$C_4H_8N_2O_7$

7. Control Status:
Controlled by MTCR

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:

11. Production Process:
Nitration of diethylene glycol with mixed nitric/sulfuric acids.

12. Production Equipment:

13. U.S. Producers:
Possibly Olin Corp., Stamford, CT; Union Carbide, Danbury CT; Ashland Chemicals, Columbus OH; Trojan Corp., Spanish Fork, UT

14. Production Capacity: Significant	**15. Cost:** Not available

16. Shipping Pack & Label:
Toxic substance. UN Hazard Class 1.1D, desensitized with >25% non-volatile, water insoluble phlegmatizer by weight.

17. Color & Form:
Colorless, oily liquid.

18. Foreign Producers:
Most countries that have Biazzi-type continuous nitroglycerin plants.

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Gelatinizer of nitrocellulose in gun and missile propellants.
21.	**Civil Uses:** Gelatinizer of nitrocellulose in gun propellants.
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition: Diferrocenylethane **2. CAS Registry No.:** 12156-05-7 **4. Acronym(s) or Trade Designation(s):** DFE	**3. Molecular Structure:** Not available

5. Synonyms:

6. Chemical Composition:
Not specified

7. Control Status:
Not controlled specifically, but controlled by the generalities of ML-8 Note 2.f; USML CAT V §121.12 b(5); and MTCR.

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
MACH I Inc.,
346 East Church Rd.,
King of Prussia PA 19406;
Tel: (215) 279-2340.
Bernard M. Kosowski, President

14. Production Capacity: Experimental quantities only.	**15. Cost:** Not available

16. Shipping Pack & Label:
Not Available

17. Color & Form:
Not available

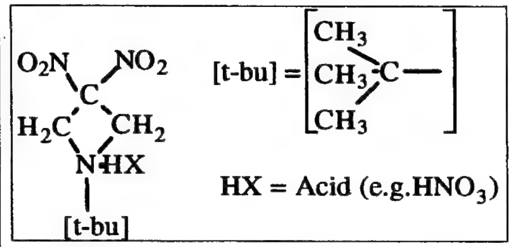
18. Foreign Producers:
None

19. Foreign Capacities: None	
20. Military Uses: Burn rate modifier and smoke reducer for solid propellants.	
21. Civil Uses:	
22. Notes: An alternative ferrocene derivative, a product of Mach I, Inc. But Mach I apparently had (in 1993) not sold any of the product in the last five years, because of the superior benefits of its superfine iron oxide products	
23. References/MILSPECS:	

1. Substance or Composition:
Dinitroazetidine-tertiary-butyl salt

2. CAS Registry No.:
More info. needed

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):

5. Synonyms:
1-tertiary-butyl-3,3-dinitroazetidine salt

6. Chemical Composition:

7. Control Status:
Controlled by ML-8 Note 5; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Confidential

12. Production Equipment:
Proprietary

13. U.S. Producers:
Aerojet Div., GENCORP, Sacramento CA (See TNAZ)

14. Production Capacity:
Limited

15. Cost:
Not available

16. Shipping Pack & Label:

17. Color & Form:
White crystalline powder

18. Foreign Producers:
None

19. Foreign Capacities:
None

20.	**Military Uses:** Precursor for TNAZ
21.	**Civil Uses:** None
22.	**Notes:**
23.	**References/MILSPECS:**

1. **Substance or Composition:** Dinitrogen pentoxide	3. **Molecular Structure:** See composition
2. **CAS Registry No.:** 10102-03-1	
4. **Acronym(s) or Trade Designation(s):**	

5. **Synonyms:** Nitrogen pentoxide Nitric anhydride	
6. **Chemical Composition:** N_2O_5	
7. **Control Status:** Controlled by MTCR	
8. **Quality:** Not specified	
9. **Precursors:** Nitric acid	
10. **Precursor Quality:** Not specifie	
11. **Production Process:** Dehydration of conc. nitric acid with phosphorus pentoxide.	
12. **Production Equipment:** Nitration plant	
13. **U.S. Producers:** Manufacturers of nitric acid; particularly manufacturers of nitrogen fertilizers	
14. **Production Capacity:** Limited	15. **Cost:** Not available
16. **Shipping Pack & Label:** No UN Hazard Class assigned; soluble in water and nitric acid.	
17. **Color & Form:** Very hygroscopic white crystals, mp 29.5°C.	
18. **Foreign Producers:** Unknown	
19. **Foreign Capacities:** Unknown	

20.	**Military Uses:** As a nitrating agent for other propellant ingredients.
21.	**Civil Uses:** Nitrating agent
22.	**Notes:** This is an unstable substance; see the comments in regard to nitrogen trioxide.
23.	**References/MILSPECS:**

1. Substance or Composition: Dinitrogen trioxide	**3. Molecular Structure:** See composition
2. CAS Registry No.: 10544-73-7	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:
Nitrogen trioxide
Nitrous anhydride
Nitrogen sesquioxide

6. Chemical Composition:
N_2O_3

7. Control Status:
USML CAT V §121.14; MTCR.

8. Quality:
Not specified

9. Precursors:
Nitric oxide and dinitrogen tetroxide

10. Precursor Quality:
Not specified

11. Production Process:
Pass nitric oxide into N_2O_4

12. Production Equipment:
Nitration plant

13. U.S. Producers:
See notes

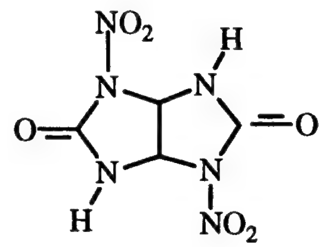
14. Production Capacity: Limited	**15. Cost:** Not available

16. Shipping Pack & Label:
See notes. UN Hazard Class 2.3, toxic gas; secondarily Class 5.1, oxidizing substance, and Class 8 corrosive substance. Transportation of the substance should be prohibited except with special authorization from a competent authority.

17. Color & Form:
Toxic, brown gas; or blue solid or liquid; it would probably be shipped as a liquid under pressure (boiling point 3.5°C). Partially dissociates to NO and NO2.

18. Foreign Producers:
Unknown

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Experimental oxidizer
21.	**Civil Uses:** None
22.	**Notes:** This substance is not widely used, is inherently unstable at room temperature, and must be produced locally in small quantities in accord with a specific demand. Experimental quantities could probably be shipped if refrigerated in Freon, and subject to international transportation safety regulations. It can be made easily if other nitration facilities are available, and in general such facilities are available in at least 17 countries outside NATO and the former Warsaw Pact countries. The substance is listed in the USML Cat V, §121.14, but bracketed with nitrogen dioxide.
23.	**References/MILSPECS:**

1. Substance or Composition: Dinitroglycoluril	**3. Molecular Structure:** 
2. CAS Registry No.: 55510-04-8	
4. Acronym(s) or Trade Designation(s): DNGU or DINGU	

5. Synonyms:
1,4-dinitroglycoluril;
Dinitroacetylenediurein;
Dinitraza(3,3,0)octone3,7dione
Glycoluril-dinitramine

6. Chemical Composition:
$C_4H_4N_6O_6$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Acetic anhydride; glycoluril; 98% nitric acid

10. Precursor Quality:
Not specified

11. Production Process:
Nitration of glycoluril in the presence of acetic anhydride

12. Production Equipment:
Could be readily made at a Bachman type RDX/HMX facility.

13. U.S. Producers:
None; has been made in limited quantities at LANL, NM

14. Production Capacity: Pilot plant quantities only	**15. Cost:** Not available

16. Shipping Pack & Label:
No UN Hazard Class assigned; but nominally a Class 1.1 explosive

17. Color & Form:
White solid

18. Foreign Producers:
SNPE, Sorgues, France;
China?

19. Foreign Capacities:
Limited

20. Military Uses:
Experimental invulnerable fill for warheads and detonating cord; ingredient of experimental, survivable missile propellants

21. Civil Uses:
Linear shaped charges as a substitute for PETN

22. Notes:
Dinitroglycoluril also known as a nitroacetylenediureins or glycoluril-dinitramine and -tetranitramine, was originally prepared in 1888 and re investigated during World War II and the Korean War period by the U.S. Army Ordnance Corps. During the latter period it was determined that several isomers of the substance can be formed and that their performance potential was equal to or better than PETN, RDX. However, the substance showed hydrolytic instability. Military interest waned rapidly.

SNPE, Sorgues, France, renewed interest in DINGU beginning in the late 1970s showing it had a density and detonation velocity of 1.94 g/ml and >8500 m/s respectively. Stability was reported to be achieved through control of the isomer content during manufacture.

DINGU has been applied in the commercial field as a substitute for PETN in linear shaped charges. It also has been shown to have favorable performance, sensitivity, and settling characteristics in comparison with RDX when mixed with molten TNT. To date it has been made only in limited quantities in the U.S. in DOE laboratories, but continues to have potential for use in less-vulnerable compositions under development.

FSU interest in the substance has not been determined. China (CH), however, synthesized DNGU, and related substances such as tetranitroethane, TNAE, possibly 15 or 25 years ago.

23. References/MILSPECS:

1. Substance or Composition: Encapsulated metals composed of aluminum, magnesium, zirconium, or beryllium	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: Not registrable	

4. Acronym(s) or Trade Designation(s):

6. Chemical Composition:
Aluminum particles encapsulated in magnesium, zirconium or beryllium; or any other particles of one of these metals encapsulated with one of the other metals.

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Powders in particle sizes <60 micro-metres whether spherical, atomized, spheroidal, flaked, [sponge], or ground. The purity is not specified; but the encapsulated metal must generally be of the same quality as that of the listed, uncoated metal; the encapsulating metals are in the form of thin layers of similar purity.

9. Precursors:
Listed, uncoated metal particles.

10. Precursor Quality:
99% or greater purity

11. Production Process:
Physical or chemical vapor deposition, as for example, of magnesium on boron or boron/aluminum alloy, and aluminum on boron or zirconium

12. Production Equipment:
Proprietary

13. U.S. Producers:
MACH I Inc.,
346 East Church Rd.,
King of Prussia PA 19406;
Tel: (215) 279-2340.
Bernard M. Kosowski, President

14. Production Capacity: Limited	**15. Cost:** > $200/lb.

16. Shipping Pack & Label:
UN Class 4, flammable solid; division depends on composition.

17. Color & Form:
Gray metallic powders.

18.	**Foreign Producers:** None
19.	**Foreign Capacities:** None
20.	**Military Uses:** Propellant fuel or pyrotechnic (flare) ingredients.
21.	**Civil Uses:** Fireworks; flares
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition: Energetic monomers, plasticizers, and polymers containing nitro, azido, nitrate, nitraza, or difluoroamino groups	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: Not registrable	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms:	
6. Chemical Composition: Various	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Not specified	
12. Production Equipment: Not applicable	
13. U.S. Producers: Various	
14. Production Capacity: Limited	**15. Cost:** Not available
16. Shipping Pack & Label: UN Hazard Class 1.1 Explosives.	
17. Color & Form: Liquid polyners	
18. Foreign Producers: Unknown	
19. Foreign Capacities: Unknown	

20.	**Military Uses:** Energetic material binders
21.	**Civil Uses:** None
22.	**Notes:** This generic entry in the control lists was introduced to anticipate the development and production of specific substances now listed individually, e.g. GAP, TVOPA, AMMO, BAMO.
23.	**References/MILSPECS:**

1. Substance or Composition: Enriched nitric acid **2. CAS Registry No.:** 8007-58-7 **4. Acronym(s) or Trade Designation(s):** IRFNA	**3. Molecular Structure:** Not applicable

5. Synonyms:
Type IIIB acid;
Inhibited red fuming nitric acid

6. Chemical Composition:
HNO_3 + about 25% NO_2 + inhibitor

7. Control Status:
Controlled by a. ML-8 Note 1a; USML CAT V §121.21; MTCR
b. ML-8e; MTCR 1.C.a.9; USML CAT V §121.12

8. Quality:
Not specified; but generally >92% HNO_2 content to be termed fuming.

9. Precursors:
HNO_3, NO_2

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Nitration plant

13. U.S. Producers:
Two producers, unspecified

14. Production Capacity: Significant	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 8, corrosive liquid; secondarily a Class 5.1 oxidizing substance and a Class 6.1, toxic substance .

17. Color & Form:
Nitric acid is a colorless or slightly yellow (due to presence of NO_2), pungent liquid, with toxic vapors. IRFNA as formulated has a deeper color, yielding a reddish or brownish appearance

18. Foreign Producers:
FSU, China, India, UK, France, Japan, etc.

19.	**Foreign Capacities:** Significant
20.	**Military Uses:** Used in foreign tactical (air defense) missiles; in U.S. used now only in obsolescent Lance missile (t-22 version uses solid propellant)
21.	**Civil Uses:** Used in Delta booster rocket motors
22.	**Notes:** The substance is also known as "inhibited red fuming nitric acid" (hence the acronym), and is essentially a mixture of nitric acid with nitrogen tetroxide. Note that non-enriched or non inhibited fuming nitric acid is specifically not embargoed by ML 8 and is among substances that the U.S. agreed to exclude from the ML as being common industrial chemicals. However, inhibited RFNA is believed to be manufactured only by two U.S. producers; the inhibiting additives, while not classified, but also not generally described, include a small proportion of hydrofluoric acid or other substances to "inhibit" the corrosion of metals. The composition could be reverse engineered if analyzed. The oxidizer is believe to be also generally available to all countries that produce liquid propellant rockets and long range missile systems.
23.	**References/MILSPECS:**

1. Substance or Composition: Ethane-1,1,1-tris(hydroxymethyl) trinitrate	**3. Molecular Structure:** See composition
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s): MTN; TMETN (qv)	

5. Synonyms:
Metrioltrinitrate;
Methyltrimethylolmethane trinitrate;
Nitropentaglycerin

6. Chemical Composition:
$CH_3C(CH_2ONO_2)_3$

7. Control Status:
Not controlled; but see TMETN

8. Quality:
Not specified

9. Precursors:
NS; See process below

10. Precursor Quality:
Not specified

11. Production Process:
Nitration of methyl trimethylol methane

12. Production Equipment:
Biaggi nitration facilities

13. U.S. Producers:
Several potential: Hercules

14. Production Capacity: Significant	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 1.1

17. Color & Form:
Heavy, colorless, odorless oil

18. Foreign Producers:
Several countries have usable facilities

19. Foreign Capacities:
Unknown

20. Military Uses:
Flash and erosion reducing agent in gun propellants. Mixed with 8% metriol triacetate (not controlled) it gelatinizes NC for use in gun, missile, and rocket propellants, e.g. in Chaparral, Hellfire, Trident systems.

21. Civil Uses:
Used in commercial high explosives and ammunition

22. Notes:
MTN is used in conjunction with polymeric binders for advanced rocket and missile propellants. Sale of the substance to PRC was denied by COCOM in September 1984, on the basis of USAF objections, because the sale or data would enhance PRC capabilities to develop a minimum smoke rocket propellant for tactical and strategic missile systems. These ingredients were used by the U.S. in, for example, the Chaparral, Hellfire, and Trident (SLBM) systems, but the U.S. had not (at least at that time) shared details of the manufacturing technology with NATO allies.

However, MTN is an alternative name for TMETN, which in combinations with TEGDN (or TEGN) is used as a plasticizer for nitrocellulose. Its method of manufacture is described in widely available literature (Ref. 1), and it may be presumed that most countries with explosion-proof nitration facilities at Biazzi nitroglycerin plants could produce it in quantity. The substance is almost as sensitive as nitroglycerin and does not have good thermal stability.

23. References/MILSPECS:
1. *Military Explosives*, Dept. Army Tech. Manual TM9-1300-214, p. 8-26, September 1984.

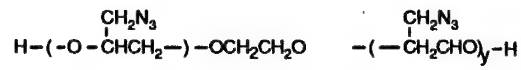
1. Substance or Composition: Ferrocene carboxylic acids	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: Not registrable	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms:	
6. Chemical Composition: Not specified	
7. Control Status: Not controlled specifically, but controlled by the generalities of ML-8 Note 2.f; USML CAT V §121.12 b(5); and MTCR.	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: Unknown	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label:	
17. Color & Form:	
18. Foreign Producers: Germany	
19. Foreign Capacities: Unknown	
20. Military Uses: Burn rate modifier and smoke reducer for solid propellants.	

21.	**Civil Uses:** Unknown
22.	**Notes:** Proposed by Germany as part of a generalization of the catocene/ferrocene derivative listing, ML-8 par. 2f.
23.	**References/MILSPECS:**

1. Substance or Composition:
Glycidylazide polymer

2. CAS Registry No.:
143178-24-9

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
GAP

5. Synonyms:

6. Chemical Composition:
$(C_3H_5N_3))_n$

7. Control Status:
Controlled by ML-8 Note 2.a; USML CAT V §121.12 b(1)

8. Quality:
Not specified

9. Precursors:
Sodium azide;
Alcohol-functionalized polyepichlorohydrin;
hexamethylene diisocyanate (HMDI);
trimethylol propane (TMP).

10. Precursor Quality:
Low molecular weight polyepichlorohydrin

11. Production Process:
GAP is produced from polyepichlorohydrin, the chloride content being replaced with azide ($-N_3$) groups from sodium azide. The terminal OH groups of GAP are then cured with -NCO groups of isocyanate (e.g., (HMDI) and cross-linked with TMP.

12. Production Equipment:
Proprietary

13. U.S. Producers:
3M Company, Specialty Chemicals Div.,
3M Center, 236-2A-01,
St. Paul MN 55144-1000.
Tel: 612 458-1392;
FAX: (612) 458-1383.
Dr. Anthony P. Manzara

14. Production Capacity:
Development quantities

15. Cost:
Not available

16. Shipping Pack & Label:
Drums

17. Color & Form:
Liquid

18. Foreign Producers:
Nippon Oil and Fats, Co. Ltd. (Japan), 200 Park Ave, New York NY 10166
Defense Research Establishment, Valcartier, Canada;
(See also notes for other potential users/producers)

19. Foreign Capacities:
Probably developmental quantities only.

20. Military Uses:
Energetic binder for solid missile propellants.

21. Civil Uses:
None

22. Notes:
The low molecular weight, alcohol-functionalized polyepichlorohydrin (qv) required as a precursor is not believed to be available outside the U.S. (except perhaps under license). The polyepichlorohydrin available in the U.S. that meets the control parameters is an experimental product of the Industrial Chemicals Division of the 3M Company known as DynamarTM, Polyepichlorohydrin Diol, HX-102.

Apart from the specific instances, the other NATO countries draw to a considerable degree on U.S. developments in this field to advance their technology: Australia, Canada, France, GE, and the UK are all involved in the preparation and evaluation of GAP through the auspices of USAF/Rocketdyne agreements. Japan and The Netherlands are working on GAP on their own initiative. U.S. technology for the small-scale manufacture of precursors and new energetic polymers also is transferred to both NATO and non-NATO countries via the open literature. For example, U.S.-developed technology for the preparation and use of GAP was released in 1990 to the open literature at an international forum where most of the world's users of military explosives were represented.

There is no evidence that the former Warsaw Pact countries produce or apply GAP. However, they are believed to have introduced azidoisocyanates for such applications.

Among non-NATO countries Brazil, Egypt, Israel, South Korea, South Africa, Sweden, and Taiwan are working on GAP on their own initiative. South Africa and South Korea are trying to make polyepichlorohydrin and have made some of their own GAP; Israel bought material from the United States (3M Company), perhaps for comparison purposes. Taiwan is trying to make the materials but the quality is very poor. The United States remains the only known source of high quality material.

A variant of the U.S. epichlorohydrin route to the synthesis of GAP was recently described by the Defence Research Establishment, Valcartier, Canada (Refs. 1, 2). It is possible that the branched GAP produced by the process will have advantages for the development of replacement missile propellants based on AP/GAP/HMX, including higher molecular weight and functionality.

Taiwan is able to make at least small quantities of the pre polymer for studies of GAP/BDNPA/BDNPF stability (Ref. 3).

23. References/MILSPECS:

1. Ahad, E., in 24th International Annual Conference of ICT; Fraunhofer-Institute für Chemische Technologie, Karlsruhe, Germany, 1993, pp. Paper P 75.
2. Ahad, E., U.S. Patent 4,882,395, 1993.
3. An-Lu Leu, Shin-Ming Shen, et al. Proceedings of 21st. International Conference of Fraunhofer Institute of Chemical Technologie, Karlsruhe, Germany 1990, p. 6-1.

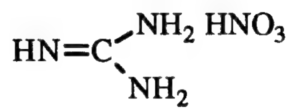
1. **Substance or Composition:** Glycidylazide polymer derivatives	3. **Molecular Structure:** Not applicable
2. **CAS Registry No.:** Not registrable	
4. **Acronym(s) or Trade Designation(s):**	
5. **Synonyms:**	
6. **Chemical Composition:** Not applicable	
7. **Control Status:** Controlled by ML-8 Note 2.a; USML CAT V §121.12 b(1)	
8. **Quality:** Not specified	
9. **Precursors:** GAP	
10. **Precursor Quality:** Not specified	
11. **Production Process:** Proprietary	
12. **Production Equipment:** Proprietary	
13. **U.S. Producers:** 3M Company, Specialty Chemicals Div., 3M Center, 236-2A-01, St. Paul MN 55144-1000. Tel: 612 458-1392; FAX: (612) 458-1383. Dr. Anthony P. Manzara	
14. **Production Capacity:** Limited	15. **Cost:** Not available
16. **Shipping Pack & Label:** Drums	
17. **Color & Form:** Liquids	
18. **Foreign Producers:** Unknown	

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Experimental energetic binders for solid missile propellants.
21.	**Civil Uses:** None
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition:
Guanidine nitrate

2. CAS Registry No.:
506-93-4

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
GuN

5. Synonyms:

6. Chemical Composition:
$CH_6N_4O_3$

7. Control Status:
Controlled by ML-8 Note 5

8. Quality:
Not specified

9. Precursors:
Calcium dicyanamide and AN

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary; see notes

12. Production Equipment:
Proprietary

13. U.S. Producers:
American Cyanamide

14. Production Capacity:
Unknown

15. Cost:
Not available

16. Shipping Pack & Label:
Not determined

17. Color & Form:
Colorless crystals

18. Foreign Producers:
Potential or actual producers are: Australia, Canada (a prime U.S. source), the UK (Royal Ordnance), Germany (Meister, Pilsen; SKW, Trostberg; and Hoechst), Italy (Colleferro), and possibly Japan. NIGU-Chemie, Trostberg was reputed to make the best quality material within NATO; Russia, Austria (Chemie Linz) and South Africa.

19. Foreign Capacities:
Unknown

20. Military Uses:
Manufacture of NQ and TAGN

21. Civil Uses:
Disinfectants and photographic chemicals.

22. Notes:
GuN is formed by reacting calcium dicyanamide with ammonium nitrate. Cyanamides are also used in the manufacture of fertilizers and weed killers. Earlier, cheaper methods of preparing NQ were based on sulfur-containing guanidine compounds, which introduced residual sulfur into the ultimate product and the propellant formulations. Reactions between sulfur and nitrocellulose in the formulations caused instabilities in storage, which delayed adoption of NQ and may have been a factor in the FSU use of an alternative approach.

The dicyanamide, or cyanamide, is manufactured within NATO in Australia, Canada (a prime U.S. source), the UK (Royal Ordnance), Germany (Meister, Pilsen; SKW, Trostberg; and Hoechst), Italy (Colleferro), and possibly Japan. NIGU-Chemie, Trostberg was reputed to make the best quality material within NATO. Austria (Chemie Linz) and South Africa are sources outside of NATO. Russia has done enough research on NQ that it must have at least a pilot plant for GN.

Guanidine nitrate is commonly manufactured in situ at or close to plants that make NQ.

23. References/MILSPECS:
MIL-C-21352

1. Substance or Composition: Hexabenzylhexaazaisowurtzitane	**3. Molecular Structure:** Classified
2. CAS Registry No.: 124782-15-6	
4. Acronym(s) or Trade Designation(s): HBIW	

5. Synonyms:
2,4,6,8,10,12-hexabenzyl-2,4,6,8,10,12-hexaazaisowurtzitane;
2,4,6,8,10,12-hexabenzyl-2,4,6,8,10,12-hexaazatetracyclo-[5.5.0.05.9.03.11]dodecane

6. Chemical Composition:
$C_{48}H_{48}N_6$

7. Control Status:
Controlled by ML-8 Note 5; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Classified

10. Precursor Quality:
Not specified

11. Production Process:
Classified

12. Production Equipment:
Classified

13. U.S. Producers:

14. Production Capacity:	**15. Cost:** Not available

16. Shipping Pack & Label:

17. Color & Form:

18. Foreign Producers:
Unknown

19. Foreign Capacities:
Unknown

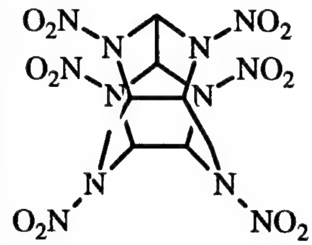
20. Military Uses:
See note

21.	**Civil Uses:** None
22.	**Notes:** HBIW is a precursor for the preparation of CL-20. Its structure, preparation, and availability are classified.
23.	**References/MILSPECS:**

1. Substance or Composition:
Hexanitrohexaazaisowurtzitane
and clathrates (See notes)

2. CAS Registry No.:
135285-90-4;
clathrates are not registrable

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
CL-20 or HNIW

5. Synonyms:
2,4,6,8,10,12-hexanitro-2,4,6,8,10,12-hexaazaisowurtzitane;
2,4,6,8,10,12-hexanitro-2,4,6,8,10,12-hexaazatetracyclo[5.5.0.05.9.03.11] dodecane

6. Chemical Composition:
$C_{12}N_{12}O_{12}$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Hexabenzylhexaazaisowurtzitane;
Tetraacetyldibenzylhexaazaisowurtzitane

10. Precursor Quality:
Not specified

11. Production Process:
Classified

12. Production Equipment:
Not specified

13. U.S. Producers: (1) Thiokol Corp., Science & Engineering, P.O. Box 707, MS 244, Brigham City, UT 84302. Tel: (801) 863-2957; FAX: (801) 863-2271. Dr. Jerald C. Hinshaw. (2) Aerojet Division, GENCORP, Sacramento CA. Tel: (916) 355 6967 Thomas G. Archibald.	
14. Production Capacity: Pilot plant capacities about 20,000 lb./yr. Goal is about 200,000 lb. per year	**15. Cost:** >$27.00 per lb.
16. Shipping Pack & Label: Hazard class 1.1D explosive.	
17. Color & Form: White crystals	
18. Foreign Producers: RARDE (U.K.); (SNPE)France	
19. Foreign Capacities: Probably laboratory quantities only.	
20. Military Uses: Advanced warheads for SMAW, Dragon, SADARM, Mk50 Torpedo, Standard missile, STAFF, Tomahawk, Osami. Minimum smoke solid propellants for Sidewinder, Tomahawk, and LOSAT	
21. Civil Uses: None	

22. Notes:

Perhaps most important currently among the polynitro poly aza compounds, or caged nitramine compounds, CL-20 is the most powerful high explosive yet synthesized and exists in several crystallographic forms, of which the eta-phase with a density of about 2.044 g/ml is possibly of most interest. The processes and properties for the manufacture of CL-20 are classified, and two or more defense contractors are scaling-up production processes (to about 200,000 lb per year) based on commercially available benzylamine and glyoxal precursors. Probably no more than 4000 lb. have yet been synthesized. The target cost of the material is about $27.00/lb, and it has potential both for high energy missile propellants and high explosive warheads.

Methods for the preparation of CL-20 have evidently been derived both in the UK (DRA) and France (SNPE). This is confirmed in the case of France by the release of the nuclear magnetic resonance spectrum of the compound, but neither they nor any other country except the United States is known to have scaled up a process.

Also of interest in this context are CL-20 clathrates, consisting of one HN_3 moiety bonded to one CL-20, or one H_2O_2 moiety bonded to two CL-20 molecules. These high density (~2.0 g/ml) derivatives of CL-20 have high potential for use as missile propellant ingredients. They are listed in the ML and USML, but are not otherwise defined.

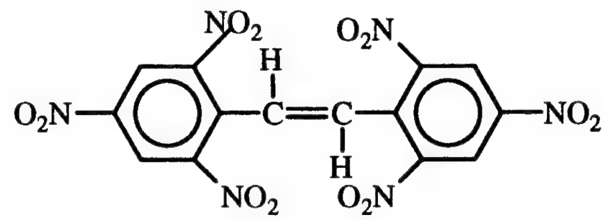
While the FSU and China are known to be doing research along similar lines to the U.S., there is no evidence that any country other than the U.S. and France has yet progressed to the stage of developing production technology, or that the materials are being investigated as something more than laboratory curiosities.

23. References/MILSPECS:

1. Substance or Composition:
Hexanitrostilbene

2. CAS Registry No.:
20062-22-0

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
HNS

5. Synonyms:
2,2',4,4',6,6'-hexanitrostilbene;
1,2-bis(2,4,6-trinitrophenyl)ethylene;
1,2-bis(2,4,6-trinitrophenyl)ethene;
1,1'-(1,2-ethenediyl);
bis(2,4,6-trinitrobenzene)

6. Chemical Composition:
$C_{14}H_6N_6O_{12}$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; NDUL 6.4

8. Quality:
Not specified, but there are four principal grades, based on particle size and known as HNS I, II, Superfine, and IV. It is the last two which are most critical for military use. (See Notes)

9. Precursors:
TNT for Shipp and Picatinny processes; or,
hexanitrobibenzyl, oxidized with copper sulfate, and other reactants for the Hungarian process.

10. Precursor Quality:
Not specified

11. Production Process:
a. Shipp process
b. Hungarian process
c. Picatinny process

12. Production Equipment:
Not specified

13. U.S. Producers:
Pantex, Amarillo TX

Ensign Bickford Industries Inc.
660 Hopmeadow St.,
P.O. Box 427, Simsbury CT 06070-0427
Tel: (203) 843-2225
FAX:(203) 843-2621
Contact: Mr. Pete McGuinness

14. Production Capacity:
30,000 lb./year(all grades)

15. Cost:
>$50/lb.

16. Shipping Pack & Label:
UN Hazard Class 1.1

17. Color & Form:
Colorless crystals, or yellow needles

18. Foreign Producers:
Royal Ordnance, Bridgewater UK;
Bofors AB, Sweden;
Hungary;
Israel;
China;
South Africa?

19. Foreign Capacities:
Limited

20. Military Uses:
Nuclear weapons fuze trains; conventional munitions fuzes; high temperature explosive bolts for military and civil space vehicles.

21. Civil Uses:
Use in oil well stimulators requiring lifetimes of 200 hr @ up to 400°F;
Space vehicles.

22. Notes:
HNS is used as a high-temperature-stable booster explosive, as a slapper detonator charge, or as a gas generator for military aircraft and aerospace applications. It is also used by oil drilling companies for oil well stimulation and perforation.

The basic manufacturing process is the Shipp process (a U.S. development) that prepares HNS from TNT.(Ref. 1) The process was used by the Chemtronics Corp.; the UK (Royal Ordnance, Bridgewater) also has a plant based on this process. Bofors AB, Sweden, likewise uses the process for the manufacture of HNS, which is added to TNT to improve its grain structure in large caliber projectiles. (Ref. 2) (The technology has not been adopted by the U.S.)
(Cont.)

22. Notes (Cont.):

The so-called Hungarian process(Ref. 3) is a modified two-step Shipp process using hexanitrobibenzyl, oxidized with copper sulfate and other reactants. According to a Chemtronics source(Ref. 4), the process was found not to work well, was hard to clean up, and was not used in production.

A third patented process, the Picatinny process(Ref. 5), was used by Chemtronics to produce several hundred pounds of HNS. This is an effective process for producing high quality HNS, but is not known to be used for production anywhere in the world.

In order for HNS to be developed reliably for several military applications, it is necessary to control the purity and grain size of HNS by controlled precipitation from an approved organic solvent. This technology for the so-called HNS I and II, and for HNS Superfine developed by DOE weapons laboratories (Sandia National Labs), is the technology which is listed in the MCTL. Most recently, a fourth grade (so-called HNS IV) has been developed by the U.S. Navy. Australia also has a process for making HNS in a fine grain size. In 1991 the only source of HNS (IV) was Pantex in the U.S., but the starting material was obtained from Bofors in Sweden.

Nothing is known of the FSU's capabilities to produce HNS but it is presumed to have at least access to limited quantities of a crude product. Likewise, it is not known whether Hungary or other former Soviet bloc countries use the Hungarian process; a reputed sample of Hungarian HNS received by Chemtronics, via an oil company, was reported to be of good quality.

The Swedish production capacity for HNS is unknown. However, the application does not require, and Bofors is not known to produce, the controlled grain sizes represented by MCTL levels. However, Sweden has the technical competence to develop equivalent products if required to do so.Israel is evidently both aware of the effect of grain size on the initiability of HNS(Ref. 6), and has at least laboratory facilities to prepare HNS by the Shipp process and precipitate controlled grain size distributions(Ref. 7). Production capabilities are not known. South Africa was also reported to be considering the manufacture of HNS at Somerchem(Ref. 8).Although in 1990 it was not clear that anything more than a laboratory scale Shipp process was used, CH(Ref. 9) had also made HNS and used it to modify the Swedish TNT process described above. Their continued efforts to develop HNS and related compounds is reflected in a more recent publication (Ref. 10).

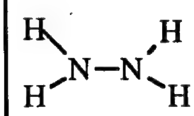
23. References/MILSPECS:

1. K. G. Shipp, *J. Org. Chem., 29,* 2620 (1964); U.S. Patent 3,505,413 (1970).
2. Sigurd Back, *International Defense Rev. 17* (11) 1748-50 (1984).
3. T. Kompolthy, G. Benex, J. Deres, L. Hajos, *Chem. Abstr. 84:58886* (1976; (Hungarian Patent T/9639 (1975).
4. Discussion, Dr. R. F. Walker with Dr. Fred Hudson, Atlantic Research Corp. Alexandria, VA, 24 January 1985.
5. G. Sollot, *J. Organ. Chem., 47,* 2471 (1981).
6. A. C. Schwartz, Report #XC-RR-71-0673, Sandia Laboratories, Albuquerque, NM (1972).
7. A. E. Hasman, M. Gvishi, and A. Solomonovici (Government of Israel, Haifa, Israel), *Prop. Explosives, Pyro. 12,* 130, 1987; b. M. Gvishi, A. Solomonovici, Ibid., *14,* 190 (1989).
8. A. J. Pool, J. J. Englebrecht, S. W. Thomas, Somerchem Pty, Discussion with Dr. R. F. Walker, Karlsruhe, FRG, 2 July 1985.
9. Y. L. Lee, et al., *Prop. Explosives, Pyro., 15,* 22 (1990).
10. Zeng-guo, F., and C. Boren, *Prop, Explosives, Pyro.* 1991, *16,* 12–15.
11. MIL-C-82903 (HNS IV)
12. NATO STANAG 4230 (Draft spec.)

1. Substance or Composition:
Hydrazine

2. CAS Registry No.:
302-01-2

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):

5. Synonyms:
Diamidogen;
Diamide

6. Chemical Composition:
N_2H_4

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR

8. Quality:
Not specified; but 99-99.5% generally required for U.S. missile applications.

9. Precursors:
Caustic soda, liquid chlorine, ammonia and sodium hypochlorite; or urea

10. Precursor Quality:
Not specified

11. Production Process:
Precursors are used to make sodium hypochlorite; the hypochlorite and ammonia are then reacted to form chloramine (NH_2Cl), which is reacted further with excess ammonia and sodium hydroxide to produce hydrazine (and salt).

Urea may also be used in place of ammonia to produce hydrazine hydrate. A continuous process was developed by the French in the early 1970s by reacting ammonia, hydrogen peroxide, and methyl ethyl ketone in the presence of a catalyst.

12. Production Equipment:

13. U.S. Producers:
Olin Corp.,
Cheshire CT.
Tel: (203) 356-4071
Dr. Karl Seefried, VP Technology.

14. Production Capacity:
The 1980s capacity was given as approx. 25,000 metric tons/year, of which 10,000 metric tons was used by the space program. Olin estimates its 1995 capacities at 3-5,000,000 lb. per year, with <1,000,000 lb/year actual production.

15. Cost:
$23.00 per lb

16. Shipping Pack & Label:
UN Hazard Class 3. 30-55 gal drums; or pressurized 6-500 gal containers; or 2500 gal bulk trailers; does not require double-walled containers but is shipped that way.

Also shipped as A-70 or A-50 blends with other hydrazine derivatives (Refs. 4,5).

The trend is expected to be towards the use of 120-250 gal. upright cylinders for fueling launch vehicles.

17. Color & Form:
Colorless, fuming hygroscopic liquid.

18. Foreign Producers:
UK; Bayer Chemical Co., Germany; and South Africa all have a high purity capability Produit Chemique Ugine Kulman, Lyons, France produced a UDMH grade suitable for the Ariane system; Brazil and Sweden have the potential to produce the substances in limited quantities; Israel and Switzerland also have the engineering competence to develop small production plants; India (Department of Space Engineering and Rocketry, Mesra) is experimenting with advanced, metallized compositions, but it is not known whether its capacities for hydrazine, UDMH, etc., are other than those of small laboratory facilities; it imports methyl cellulose from the UK. Russia; and China produce a lower quality material that does not meet U.S. specs.
(See notes)

19. Foreign Capacities:
Approach 25,000 metric tons per year in West Europe; capabilities in the rest of world probably at least as great. (See notes)

20. Military Uses:
Propellant ingredient used in liquid propulsion systems for strategic and heavy tactical surface to surface missiles; supplanted to a considerable degree in the U.S. by the use of large solid propellant motors. A70 blend still used in EPU units of F-16 and EU-2.

21. Civil Uses:
Liquid propellant ingredient for commercial space applications (Upper stages of Titan 4; Delta , and Atlas propulsion). Has been applied (not too successfully) in blasting agents; and as oxygen scavengers for the prevention of corrosion of boilers, boiler tubes, and oil well casings.

22. Notes:
Hydrazine and derivatives were considered for removal from the MCTL and ML control lists because of their worldwide availability. However, they have been retained because of their relevance to proliferation control and listing in the MTCR. They are used together with red fuming nitric acid (IRFNA) and N_2O_4 as liquid propellants for rockets and may be gelled or emulsified to control their rheology and other properties using methyl cellulose or a similar agent. Metal powders or metal hydrides of the type discussed above may also be added to improve the energy content.

22. Notes :

Hydrazine (anhydrous) was first prepared in 1894, although its salts and derivatives were prepared almost 20 years earlier; its toxicity restricts its application. It was first used as a rocket fuel in World War II by the Germans, together with hydrogen peroxide, oxygen or fuming nitric acid as the oxidizer. The high quality material now considered to necessary to meet U.S. reliability standards falls in the 99-99.5% range, whereas 'normal' material is in the 98-98.5% range. Lower quality material is assumed to be acceptable to some countries.

Russia produces hydrazine, conducts research on its derivatives, and has the potential to develop gelled, metallized, and hydride compositions, at least on a small scale. Production capabilities and capacities for the more advanced formulations are unknown, but can probably be developed from indigenous resources. For this reason, neither the manufacturing processes nor the substances were included in the 1989 edition of the MCTL, although the bulk substances are listed in the Annex to the Missile Technology Control Regime and Item 8 of the International Munitions List. The oxidizers used with hydrazine were disembargoed in ML 8 in 1983. Hydrazine offered for sale by Russia has since been reported not to meet U.S. specs. The extent of the capability in other countries has not been evaluated. However, U.K., South Africa, France, and Germany produce high quality material. Brazil Africa, and Sweden may be presumed to have the potential to produce the substance in limited quantities. Israel and Switzerland also have the engineering competence to develop production plants. India (Department of Space Engineering and Rocketry, Mesra) is experimenting with advanced, metallized compositions, but it is not known whether its capacities for hydrazine, UDMH, etc., are other than those of small laboratory facilities; it imports methyl cellulose from the UK. The quality of Chinese hydrazine has been reported not to meet requirements for U.S. space launched vehicles, even when launched in China; the Olin material is also reported to be the only material acceptable for satellite use. Apart from missile applications, China must have a substantial capability for the manufacture of hydrazine and its derivatives, because of its use of an industrial blasting agent, designated SJY. This is composed of hydrazine hydrate, hydrazine nitrate and an additive, and has a claimed detonation velocity of 8475 m/s. This is very similar to a composition known as Astrolite, which was a derivative of hydrazine missile propellant technology and was purveyed in the U.S. and Europe during the early 1970s also as a blasting agent, but was never adopted either for civil or military applications.

It has been proposed in the recent past that hydrazinium nitroformate and nitroformate salts be added to this item. Hydrazinium nitroformate is rarely used, has been investigated since 1965, and is still regarded as being primarily of experimental interest. It is believed made only a few pounds at a time by Rocketdyne.

Although the substance is widely-available and used, it should be noted that a less effective, and toxic, alternative was and probably still is used by the FSU and its overseas customers; possibly also by CH. Known generically as Tonka the hypergolic compositions with IRFNA consist of one part xylidine (Ref. 2) (dimethylaniline) to one or two parts triethylamine. A specific composition designated Tonka 250 was used by Germany during World War II and had the composition 57 percent xylidinine–43 percent triethylamine and Salbei (98–100 percent HNO_3) (Ref. 3). There are six isomers of xylidine, which may also be known as aminoxylene, aminodimethylbenzene, or dimethylphenylamine. Presumably care in obtaining reproducible mixes of the xylidines is necessary to achieve satisfactory rocket motor performance. The compositions are not known to have been used in the U.S., but monitoring of international sales may be justified to meet the objectives of the MTCR.

23. References/MILSPECS:

1. MIL 26536-D.
2. Fauvreau, J., *Memorial des Poudres* **1949**, *31*, 300.
3. Anon., "Handbook of Guided Missiles of Germany and Japan," Department of Defense, 1946.
4. MIL 87930.(A-70).
5. MIL 27402-B (A-30).

1. Substance or Composition:
Hydrazine nitrate

2. CAS Registry No.:
37836-27-4

3. Molecular Structure:

$$\begin{array}{l} NH_2 \\ | \\ NH_2\ HNO_3 \end{array}$$

4. Acronym(s) or Trade Designation(s):
HN;
HzN

5. Synonyms:
Hydrazinium nitrate;
Hydrazine mononitrate

6. Chemical Composition:
$H_5N_3O_3$; or $N_2H_5NO_3$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Hydrazine; nitric acid

10. Precursor Quality:
Not specified

11. Production Process:
Addition of nitric acid to hydrazine

12. Production Equipment:
Not specified

13. U.S. Producers:
Rocket Research Co.; Olin Aerospace Corp., Redmond WA. Tel: (206) 885-5000. Mr. Doug. Huxstable.

14. Production Capacity:
100 lb per year; probably no more than 100 lb made over 1990-1995 period.

15. Cost:

16. Shipping Pack & Label:
No UN Hazard Class assigned; but a 1.1D explosive.

17. Color & Form:
White crystals

18. Foreign Producers:
China

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Solid propellant; thrusters
21.	**Civil Uses:** Ingredient of liquid blasting explosive Astrolite and Chinese SJY composition.(See notes under hydrazine)
22.	**Notes:** HN has not been made by Rocket Research for high explosive use for over twenty years. The material is not currently made for sale, but only for experimental use in Rocket Research's own engineering development of propulsion systems.
23.	**References/MILSPECS:**

1. Substance or Composition: Hydrazine perchlorate	**3. Molecular Structure::** NH_2 | $NH_2 \cdot HClO_4$
2. CAS Registry No.: 27978-54-7	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms: Hydrazinium perchlorate Hydrazinium(1+) perchlorate	
6. Chemical Composition: $H_5N_2O_4Cl$; or $N_2H_5ClO_4$	
7. Control Status: Controlled by ML-8 Note 1a; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Hydrazine; $HClO_4$	
10. Precursor Quality: Not specified	
11. Production Process: Addition of concentrated $HClO_4$ to aqueous hydrazine solution	
12. Production Equipment: Not specified	
13. U.S. Producers: None	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label: No UN Hazard Class assigned; but a 1.1D explosive.	
17. Color & Form: White crystals	
18. Foreign Producers: Unknown	
19. Foreign Capacities: Unknown	

20.	**Military Uses:** Was investigated as a rocket propellant over 25 years ago.
21.	**Civil Uses:**
22.	**Notes:** There are no known current producers of this substance. It could probably be made by: Rocket Research Co.; Olin Aerospace Corp., Redmond WA. Tel: (206) 885-5000. Mr. Doug. Huxstable. SACHEM, Inc., 821-T East Woodward, Austin TX. Tel: (512) 444-3626. Mr. Scott McCoy. Also has a capability, but does not actually produce.
23.	**References/MILSPECS:**

1. Substance or Composition: Hydrogen peroxide of >85% concentration	**3. Molecular Structure::** See composition
2. CAS Registry No.: 7722-84-1	
4. Acronym(s) or Trade Designation(s): T-Stuff, strictly 82% conc., but more generally used; Aurol; Neuralin; Subsidolare names used for 80-86% concentrations	

5. Synonyms:
Hydrogen dioxide

6. Chemical Composition:
H_2O_2

7. Control Status:
Controlled by USML CAT V §121.14

8. Quality:
>85% aqueous solutions; H_2O_2 solutions are stabilized for storage and shipment with small amounts of acetophenetidin inhibitor.

9. Precursors:
Barium oxide, sulfuric acid, or 2-ethylanthraquinone

10. Precursor Quality:
Not specified

11. Production Process:

a. Autoxidation of 2-ethylanthrahydroquinone, or other alkyl anthrahydroquinone; or
b. Electrolytic oxidation of conc. H_2SO_4, or ammonium bisulfate; or
c. Addition of BaO_2 to $H_2SO_4(aq)$; concentration of the H_2O_2 by evaporation under reduced pressure.

Process a. is the most used process.

12. Production Equipment:
Proprietary

13. U.S. Producers:
Dupont Chemical Co

14. Production Capacity: Significant	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 5.1, oxidizing substance; secondary risk Class 8 , corrosive substance. Shipped in amber glass bottles and carboys; aluminum drums; polyethylene drums with fiber and steel overpack; tank trucks; and tank cars.

17.	**Color & Form:** Colorless, or faint blue syrupy liquid
18.	**Foreign Producers:** Widely available, at least in dilute solutions
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Missile propellant oxidizer
21.	**Civil Uses:** Bleaching, deodorizing textiles, wood pulp, hair, fur, source of inorganic oxidizers for paper industry, manufacture if numerous industrial chemicals, disinfectant, cosmetic agent, etc. (Usually in more dilute concentrations than listed.)
22.	**Notes:** MIL-H-22868
23.	**References/MILSPECS::** Unknown

1. Substance or Composition: Hydroxylammonium nitrate **2. CAS Registry No.:** 13465-08-2 **4. Acronym(s) or Trade Designation(s):** HAN	**3. Molecular Structure:** See composition

5. Synonyms:
Hydroxylamine nitrate

6. Chemical Composition:
$NH_2OH.HNO_3$; or $N_2H_4O_4$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified; see process below

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary. Nominally, react $NH_2OH.HCl$ with silver nitrate; or $(NH_2OH)_2SO_4$ with barium nitrate.
See Notes

12. Production Equipment:
Proprietary

13. U.S. Producers:
Sachem Inc.,
821 E. Woodward,
Austin TX.
Tel: (512) 444-3626
Mr. Scott McCoy.

14. Production Capacity: 10,000 gals/year	**15. Cost:** $30.00 /gal

16. Shipping Pack & Label:
55 gallon drums, 24 % active in water solution

17. Color & Form:
White crystals (MP 48°C); Odorless, colorless liquid solution as transported

18. Foreign Producers:
UK; China

19. Foreign Capacities:
Significant

20. Military Uses:
Liquid propellant ingredient for rockets, guns, and torpedoes. See Notes.

21. Civil Uses:
Plant clean up during plutonium re-cycling. Possible air bag gas generator. (See Notes)

22. Notes:
Hydroxylammonium nitrate and hydroxylammonium perchlorate have been employed for many years as liquid propellants both for rockets and guns, and for torpedo propulsion units. They are ingredients of a composition known as Otto fuel, used in U.S./NATO torpedoes. Their inclusion in the MCTL derives primarily from their listing in the MTCR. The substances are widely available and comparatively easily made. A paper presented in Germany in 1993 (Ref.) suggests that the substance is under investigation in CH, possibly as a component of a less-vulnerable gun propulsion system. Apart from MTCR considerations, current interest in the substances in the U.S. and UK hinges on their potential as liquid gun propellants for tank guns and howitzers. Typical HAN-based formulations have been designated LPG 1845 and LPG 1846 in the U.S. and LP101 and 102 in the UK. Currently, the US designation of choice is LP XM46.

LP XM46 consists of 60.8% HAN, 20% water, and 19.2% triethanolamine nitrate (TEAN) and is the proposed propellant for the Crusader, advanced field artillery system; TEAN is not listed in control documents and is prepared from ammonia, ethylene oxide, and nitric acid. The existing production base for HAN is inadequate to meet the anticipated 3,000,000 kg/year Crusader requirement, so the Army is developing an enlarged base, and hoping to reduce the current cost from about $70/kg to <$10/kg by the year 2006. As an alternative to Sachem's proprietary process, the Olin Corp, Charleston TN has developed a 100,000 kg/yr. pilot plant for a continuous process based on the electrolysis of nitric acid to yield HAN and HNO_3, followed by treatment with ammonium hydroxide. Thiokol, Elkton MD is also developing a 100,000 kg/yr. pilot plant to produce HAN by a batch process from sodium hydroxide and hydroxylamine sulfate(HAS). Thirdly, Allied Signal at Des Plaines IL is extending its existing HAS production base to produce HAN by a continuous process.

These developments are expected to be favorable for the future used of XM46 or a similar composition to replace Otto fuel for torpedoes; replace AP in booster rocket motors for both civil and military applications; be usable in Hellfire and LOSAT for signatureless propellants; be adaptable for Navy fire support; and to be an igniter system for ETC gun systems. It also has potential for application to replace sodium azide as an automobile air bag propellant.

23. References/MILSPECS:

1. Wenzhou, F., in *24th. International Conference of ICT*, Fraunhofer-Inst. für Chemische Technologie, Karlsruhe, Germany, 1993, pp. Paper P85.
2. MIL-P-71158

1. Substance or Composition: Hydroxylammonium perchlorate	**3. Molecular Structure:** See composition
2. CAS Registry No.: 15588-62-2	
4. Acronym(s) or Trade Designation(s): HAP	

5. Synonyms:
Hydroxylamine perchlorate

6. Chemical Composition:
$NH_2OH.HClO_4$; or NH_4ClO_4

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified; but see process below

10. Precursor Quality:
Not specified

11. Production Process:
React $NH_2OH.HClO_4$ or NH_4ClO_4 with barium chlorate

12. Production Equipment:
Unknown

13. U.S. Producers:
None known, but see HAN for potential producers.

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label:
Probably a UN Hazard Class 1.3 Explosive; lined drums.

17. Color & Form:
White crystals but shipped as water-alcohol solution.

18. Foreign Producers:
UK

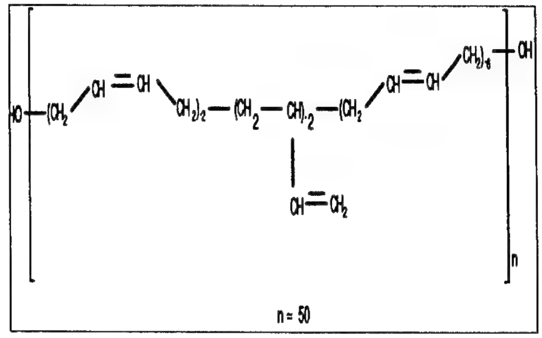
19. Foreign Capacities:
Unknown

20.	**Military Uses:** Liquid propellant ingredient for rockets, guns, and torpedoes.
21.	**Civil Uses:** Unknown
22.	**Notes:** Hydroxylammonium perchlorate (and nitrate) have been used for many years as liquid propellants both for rockets and guns, and for torpedo propulsion units. They are ingredients of a composition known as Otto fuel, used in U.S./NATO torpedoes. Their inclusion in the MCTL derives primarily from their listing in the MTCR. The substances are widely available in significant but limited quantities and are comparatively easily made. Apart from MTCR considerations, current interest in the substances in the U.S. and UK hinges on their potential as liquid gun propellants for tank guns and howitzers.
23.	**References/MILSPECS:**

1. Substance or Composition:
Hydroxylterminated polybutadiene

2. CAS Registry No.:
69102-90-5

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
HTPB;
R45M;
Butarez-HTS

5. Synonyms:

6. Chemical Composition:
$[C_4H_6]/_n]$

7. Control Status:
Controlled by:
a. ML-8 Note 2;
b. USML CAT V §121.12;
c. MTCR (CAT 1.C.b.2)

8. Quality:
a. With a hydroxyl functionality of <2.16, a hydroxyl value of <0.77 meq/g, and a viscosity at 30°C of <47 poise
b. With a hydroxyl functionality of (<)2.28, a hydroxyl value of (<)0.77 meq/g and a viscosity of 30°C of 47 poise.
c. MTCR controls without qualification.

9. Precursors:
Butadiene; ethylene oxide; alkali metals; epoxide or aziridine curing agents

10. Precursor Quality:
Not specified

11. Production Process:
In the basic process tetrahydrofuran, lithium metal, and naphthalene are reacted at - 78° for 2 days. Gaseous butadiene is then bled in for 8 hours, followed by the introduction of ethylene oxide.

12. Production Equipment: Proprietary	
13. U.S. Producers: (1) Sartomer Co., Channelview TX (owned by Atochem); (2) Philips Petroleum Co. Bartlesville, OK. Tel: (918) 661-6730. Darlene Wright	
14. Production Capacity: 1.0-1.3 million lb per year	**15. Cost:** $1.25 per lb
16. Shipping Pack & Label: Drums, tank cars.	
17. Color & Form: Liquid	
18. Foreign Producers: Atochem, subsidiary of Elf-Aquitaine, France; Idimitsu Petrochemical Co., Japan (HT only?); NIPPON OILS AND FATS (JAPAN) Brazil (available in both HT and M qualities); China (available in both HT and M qualities); Russia (available only in HT quality?) Italy (SNIA-BPD0. Pilot plant only?) Taiwan (under license from Japan) India (Indian Space Research Organization, Andhra Pradesh)	
19. Foreign Capacities: See the general notes relating to PBAA/N.	
20. Military Uses: R45M quality used as binder for solid (AP, HMX) missile propellant; other qualities are used for several military systems (See notes).	
21. Civil Uses: Coatings; construction products; waterproof membranes; electrical potting compounds, insulators, circuit boards. R45M quality is usable, but not necessary for civil applications; the space shuttle uses R45HT quality.	

22. Notes:

In 1983 proposals to include HTPB in ML 8 were dropped following assurances that it would remain listed in IL 1801 (and the related ECN 1801A). Following a review of the availability and uses of the different grades of HTPB in the 1986–1988 period, it was recommended that only the military grade, R-45M, be controlled. It was not listed in the 1989 edition of MCTL Section 20.2, but was re-introduced in the 1992 MCTL 12.7 and in the USML because HTPB was listed in the MTCR. HTPB of higher quality than R45M was introduced into ML 8 in 1992. The MTCR covers HTPB without reference to its quality.

HTPB has numerous commercial applications, for example, as a window sealant, a hydrophobic coating and waterproof membrane, potting compound, backing for brake pads; and in the paint, chemical process, and food industries. There are three recognized grades: R45M (military), R45AS (aerospace), and R45HT (mastic). These differ primarily in that the military grade has a lower hydroxyl functionality (typically lower than the 2.4-2.6 of R45HT)) and density than the mastic; the aerospace grade is a center cut between the other grades. The R45HT and R45AS qualities were not considered to meet the original, proposed ML control levels but are nevertheless used, for example, in the space shuttle, and MLRS. They probably would also be considered adequate for plastic bonded, high explosive applications. HTPB typically is reacted with polyisocyanates to form a polyurethane binder within propellant and high explosive matrices.

It is cheaper, more widely available, easier to work with, and has a significantly greater commercial market than CTPB; its lower viscosity (nominally 50 poise at 30° C) and better aging and curing characteristics are the prime reasons for its selection by propellant formulators. More particularly, the military grade, R-45M, is preferred because it is the only grade which imparts desirable low temperature physical properties to current strategic missile propellants, including Peacekeeper and most tactical missiles. The low temperature physical properties are not essential in countries not subject to sub-zero climatic conditions for prolonged periods, nor are the aging characteristics important if the missiles are to be produced and fired without an intervening period in long-term storage. The lower cost of the non-military grades is also an incentive for their application in U.S./NATO systems subject to high-use rates, and in countries seeking to produce cheaper systems than those of the U.S./NATO countries.

It is also important to recognize that several of the properties that are crucial for the optimal blending and storage of formulations are not stable. The brands illustrated in the Sartomer Co.'s technical bulletin show, for example, an approximately 10 percent increase in viscosity during storage at room temperature over a year, but a 300% increase over 2-4 months at 66° C. An Australian defense establishment reported in 1988 that after shipment across the Pacific Ocean the properties of R-45M were indistinguishable from those of R-45HT. It was reported in 1989 that the mechanical properties of formulations based on R-45M have also been found to deteriorate after 6 months in storage.

The details of the processes for manufacturing and differentiating the grades of HTPB are proprietary. In the United States HTPB is manufactured primarily by the Sartomer Co. in Channelview, Texas. In the late 1980s the plant employed about 200 people, with gross sales of $50–100 million per annum, evenly distributed over its four primary product lines. These include the commercial R45HT grade with a hydroxyl functionality in the range or 2.4–2.6; the military grade, R45M, with a functionality typically between 2.2–2.4; and an aerospace grade, R45AS which is a center cut between the other functionality ranges. Production figures given in May 1988 were as follows:

R45HT	8-9 million lb (for commercial applications)
R45M	1.0-1.3 million lb (for military applications)
R45AS	1.8 million lb (bulk non-commercial application, e.g., MLRS)

(Atlantic Research, however, uses the HT grade for this application). **(Cont.)**

22. Notes (Cont.):

It was also reported at that time that Idimitsu Petrochemical Co. in Japan was licensed to make R45HT only, and that a similar arrangement was being planned for Europe.

Since then (late 1988) the Sartomer Company's HTBP resin process has been sold to Atochem of France (a subsidiary of the Elf-Aquitaine group), both the product and technology for R45HT being included in the sale. The military (R45M) technology was sold to the New Jersey-based operation of the company with no release of the technology or product to France being permitted without a license. The Sartomer plant is 35 years old, is totally paid for, and permits HTPB to be sold for about \$1.25/lb. In 1988 plants were estimated to cost about \$1.00 per lb of estimated capacity, and the total worldwide production (mainly of the HT grade) exceeded 12 million pounds.

The Sartomer products were protected by patents that were due to expire. Two U.S. companies have alternative processes in use or under development and were in 1988 waiting to introduce competitive products.

One of these, manufactured by an anionic process, is claimed to be a better controlled, higher quality product than R45M, with a well-defined molecular weight of about 2500 and a functionality of about 2.2. It has been employed in experimental formulations by Hercules and found to have superior stability and low temperature(-65° F) physical properties when used in propellant formulations. It has also been investigated by the Navy for the development of shock resistant high explosives. References to a related product, Butarez-HTS, used in the Egyptian development of low sensitivity, nitramine high explosives suggests that a precedent already exists for the export of such material, at least for experimental purposes. (Hydroxyl value 0.95 meq. OH/g HTPB; viscosity 11 Pa.s at 20° C.)

The second company has developed a radically different, non-peroxide process, using peracetic acid, which it was in 1988 waiting to introduce.

Since then countries such as India have proceeded with the development of their own HTPB technology for missile/space-launch applications; undertaking their own HTPB polymerizations, and purchasing butane diol(BDO) chain-extender and trimethylol propane (TMP) and toluene diisocyanate cross-linking agents from Germany (Ref. 3).

23. References/MILSPECS:

1. International Institute of Synthetic Rubber Producers, 2077 S. Gessner Road., Suite 133, Houston TX 77063. Tel; (713) 783-7511. Bill Tessner, President, has helpful info. on world-wide availability of synthetic rubbers.
2. MIL-H-85497 (AS)
3. G. Govindan and S. K. Athithan. *Propellants, Explosives, Pyro.*, 19, 240-244 (1994).

1. Substance or Composition: Iron oxide **2. CAS Registry No.:** 1309-37-1 **4 Acronym(s) or Trade Designation(s):** Hematite; Pyrocat™	**3. Molecular Structure:** Not applicable

5. Synonyms:

6. Chemical Composition:
alpha-Fe_2O_3

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Fine powder with a specific surface greater than 250 sq. meters per gram and an average particle size of 0.003 micrometers or less.

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Product of United Technologies, Chemical Systems Div. licensed to:
Mach I Inc. 346 East Church Rd., King of Prussia, PA 19406.
Tel: (215) 279-2340; FAX (215) 279-6605.

14. Production Capacity: Unknown	**15. Cost:** About 1/6 cost of Catocene

16. Shipping Pack & Label:

17. Color & Form:
Reddish brown

18. Foreign Producers:
None

19. Foreign Capacities:
None

20.	**Military Uses:** Substitute catalyst for ferrocenes in some missile propellants
21.	**Civil Uses:** None
22.	**Notes:** Superfine iron oxide is not known to be available outside the U.S., but fine iron oxide is widely used in the FSU, CH, India, for example, in addition to U.S./NATO countries. It is a burning rate modifier or catalyst to increase the burning rate, with controlled pressure exponents for the more powerful solid missile propellants. The listed product is alpha-Fe_2O_3 (Hematite), sometimes marketed under the trade name PYROCAT, and has a very large surface area and a high catalytic activity. It is manufactured and sold by MACH I Inc. under license to United Technologies Chemical Systems. Individual particles of the Superfine material are only 30 Ångstroms in diameter and have a specific surface of 275 m^2/g. This is an order of magnitude larger than typical NATO products, such as BASF L2817, and permits the use of much smaller concentrations in AP-containing missile propellants, yielding perhaps 5 second increases in specific impulse. In some missile propulsion systems it is an effective replacement for the hazardous ferrocenes (q.v.).
23.	**References/MILSPECS:**

1. Substance or Composition: Iron powder produced by reduction of iron oxide with hydrogen	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: 7439-89-6	
4. Acronym(s) or Trade Designation(s): NX-1000	

5. Synonyms:

6. Chemical Composition:
Fe

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.21

8. Quality:
Powder with an average particle size of 3 micrometres or less produced by reduction of iron oxide with hydrogen

9. Precursors:
Iron oxide

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Ametek, Special Metals Div., Wallingford CT

14. Production Capacity: 20,000 lb/year	**15. Cost:** $25.00 per lb

16. Shipping Pack & Label:
UN Hazard Class 4.2, a substance liable to spontaneous combustion.

17. Color & Form:
Dark gray metallic powder

18. Foreign Producers:
None known for material of listed quality; FSU and probably other NATO countries, China, India, etc. produce lower quality material for ordnance and fireworks applications.

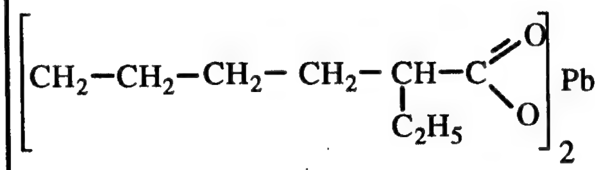
19. Foreign Capacities:

20.	**Military Uses:** Thermal batteries in missiles, including nuclear weapons. Fuzes for conventional munitions.
21.	**Civil Uses:** Lower quality material used in fireworks.
22.	**Notes:** The listed material provides essential "green" strength when pressed with $KClO_4$ for fuze applications. Lower quality material is also used for conventional munitions; for example, Exide (Edison) iron is also 2-3 microns, but is prepared by a different method.
23.	**References/MILSPECS:**

1. Substance or Composition:
Lead 2-ethylhexoate

2. CAS Registry No.:
301-08-6

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):

5. Synonyms:
Lead ethylhexoate

6. Chemical Composition:
$C_{16}H_{28}O_4Pb$

7. Control Status:
Not listed - previously listed, possibly on IL

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
The Shepherd Chemical Co.
4900 Beech St.,
Cincinnati OH 45212
Tel: (513) 731 1110;
Fax (513) 731-1532
Mr Bayard Pelser.

14. Production Capacity:
Unknown

15. Cost:
Not available

16. Shipping Pack & Label:
Unknown

17. Color & Form:
Brown amorphous powder

18. Foreign Producers:
Unknown

19. Foreign Capacities:
Unknown

20. Military Uses:
Ballistic modifier for missile propellants, particularly double base (NC/NG) propellants.

21. Civil Uses:
Paint and varnish drier

22. Notes:

23. References/MILSPECS:
MIL-L-17699

1. Substance or Composition: Lead beta resorcylate	**3. Molecular Structure:** See composition
2. CAS Registry No.: 20936-32-7	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:
Normal or Dibasic lead beta resorcylate
Lead-2,4-dihydroxy benzoic acid

6. Chemical Composition:
$Pb[O(O)C\ C_6H_3(OH)_2]_2$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
The Shepherd Chemical Co.
4900 Beech St.,
Cincinnati OH 45212
Tel: (513) 731 1110;
Fax (513) 731-1532.
Mr Bayard Pelser.

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label:
Unknown

17. Color & Form:
White powder

18.	**Foreign Producers:** None
19.	**Foreign Capacities:** None
20.	**Military Uses:** Ballistic modifier for missile propellants
21.	**Civil Uses:** Unknown
22.	**Notes:** There are several technical grades of material with associated product designation, over 95 percent of which are for use in military propellants. There are no known foreign producers, in contrast to the situations for various lead and copper salts.
23.	**References/MILSPECS:** There was no MIL SPEC in 1980, but a classified (?) Navy purchase description NASC WS1591.

1. Substance or Composition: Lead citrate	**3. Molecular Structure:** See composition
2. CAS Registry No.: 14450-60-3	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms:	
6. Chemical Composition: $Pb_3(C_6H_5O_7)_2 \cdot 3H_2O$	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Unknown	
12. Production Equipment: Unknown	
13. U.S. Producers: Unknown	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label:	
17. Color & Form: Crystalline Powder	
18. Foreign Producers: FSU	
19. Foreign Capacities: Unknown	
20. Military Uses: Propellant burning rate modifier.	
21. Civil Uses:	

22. Notes: There are known foreign producers of lead and copper malates, stannates, salicylates, etc. Their application was originally of FSU origin. They are no longer listed in the MTCR.	
23. References/MILSPECS:	

1. Substance or Composition: Lead malate	**3. Molecular Structure:** See composition
2. CAS Registry No.: 19136-34-6	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:

6. Chemical Composition:
$Pb(C_4H_4O_5)\Sigma 3H_2O$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Known

12. Production Equipment:
Known

13. U.S. Producers:
Known

14. Production Capacity: Known	**15. Cost:** Known

16. Shipping Pack & Label:

17. Color & Form:
White powder

18. Foreign Producers:
FSU

19. Foreign Capacities:
Known

20. Military Uses:
Propellant burning rate modifier.

21.	**Civil Uses:** Known
22.	**Notes:** There are known foreign producers of lead and copper malates, stannates, salicylates, etc. Their application was originally of FSU origin. They are no longer listed in the MTCR.
23.	**References/MILSPECS:**

1. Substance or Composition: Lead salicylate	**3. Molecular Structure:** See compositions
2. CAS Registry No.: 15748-73-9	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:

6. Chemical Composition:
$Pb[O(O)CC_6H_4OH]_2H_2O$ and $Pb[C_4H_4(OH)COO]_2$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
The Shepherd Chemical Co.
4900 Beech St.,
Cincinnati OH 45212
Tel: (513) 731 1110;
Fax (513) 731-1532.
Mr Bayard Pelser.

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label:

17. Color & Form:
Crystalline powder

18. Foreign Producers:
FSU

19. Foreign Capacities:
Unknown

20.	**Military Uses:** Burning rate modifier for double base propellants
21.	**Civil Uses:** Unknown
22.	**Notes:** There are known foreign producers of lead and copper maleates, stannates, salicylates, etc. Their application was originally of FSU origin. They are no longer listed in the MTCR.
23.	**References/MILSPECS:** MIL-L-13788 MIL-L-17700

1. Substance or Composition: Lead stannate **2. CAS Registry No.:** 12036-31-6 **4. Acronym(s) or Trade Designation(s):**	**3. Molecular Structure:** Not available
5. Synonyms:	
6. Chemical Composition: Not determined	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Not specified	
12. Production Equipment: Not specified	
13. U.S. Producers: Unknown	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label: Not specified	
17. Color & Form: Crystalline powder	
18. Foreign Producers: FSU	
19. Foreign Capacities: Unknown	
20. Military Uses: Propellant burning rate modifier.	

21.	**Civil Uses:** Unknown
22.	**Notes:** There are known foreign producers of lead and copper malates, stannates, salicylates, etc. Their application was originally of FSU origin. They are no longer listed in the MTCR.
23.	**References/MILSPECS:**

1. Substance or Composition: Lead-copper chelates of beta-resorcylate/salicylate	**3. Molecular Structure:** Unknown
2. CAS Registry No.: 68411-07-4 (CAS registration is under review).	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms: Lead-copper chelates of beta-resorcylate Lead-copper salicylates	
6. Chemical Composition:	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12	
8. Quality: MILSPEC MIS-30864; MILSPEC MIL-B-85735	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: The Shepherd Chemical Co. 4900 Beech St., Cincinnati OH 45212 Tel: (513) 731 1110; Fax (513) 731-1532. Mr Bayard Pelser.	
14. Production Capacity: Tonnes/year	**15. Cost:** About $15.00 per lb?
16. Shipping Pack & Label: Not determined	
17. Color & Form: Not available	

18.	**Foreign Producers:** None known
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Burning rate modifier for propellants.
21.	**Civil Uses:** Has undetermined civil use(s).
22.	**Notes:** There are several technical grades of material with associated product designations, over 95 percent of which are for use in military propellants. There are no known foreign producers, in contrast to the situations for various lead and copper salts.
23.	**References/MILSPECS:** MILSPEC MIS-30864; MILSPEC MIL-B-85735

1. Substance or Composition: Lithium	**3. Molecular Structure:** Not applicable
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:

6. Chemical Composition:
Li

7. Control Status:
Not controlled, but a substance of interest.

8. Quality:
0.5 micrometer to 9/16 inch spherical powders and shapes

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Reduction of Lithium oxides.

12. Production Equipment:
Proprietary

13. U.S. Producers:
Lithco;
Foote Chemical. (See notes)

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Class 4.3

17. Color & Form:
Gray powder

18. Foreign Producers:
U.K.

19. Foreign Capacities:
Unknown

20. Military Uses:
Stored chemical energy propulsion system (SCEPS) used in developmental MK 50 torpedo.

21.	**Civil Uses:** Chemical batteries
22.	**Notes:** Sundstrand Corp., Rockford IL 61125. Tel: (815) 394-2166. Contact: Mr. John Beaufort. SCEPS developer. Proposed as an item of interest by MICOM (1994)
23.	**References/MILSPECS:** MIL-L-48772A

1. Substance or Composition: Lithium Hydride	**3. Molecular Structure:** Not applicable
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:

6. Chemical Composition:
LiH_2

7. Control Status:
Not controlled, but an item of interest

8. Quality:
Not specified; the substance is probably non-stoichiometric

9. Precursors:
Li; hydrogen

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
MACH I Inc.,
346 East Church Rd.,
King of Prussia PA19406;
Tel: (215) 279-2340. Bernard M. Kosowski, President

14. Production Capacity: Limited	**15. Cost:** >$200/lb.

16. Shipping Pack & Label:
UN Hazard class 4.3; in contact with water emits flammable gases.

17. Color & Form:
Gray metallic powder

18. Foreign Producers:
Unknown

19. Foreign Capacities:
Unknown

20.	**Military Uses:** High energy propellant ingredient
21.	**Civil Uses:** Unknown
22.	**Notes:** Proposed for control by MICOM 1994
23.	**References/MILSPECS:** MIL-L-12039D

1. Substance or Composition: M1 thickener	**3. Molecular Structure:** Not applicable
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms:	
6. Chemical Composition: A mixed Al soap , 50% coconut oil derivs., 25% naphthenic acids, 25% oleic acid.	
7. Control Status: Controlled by ML-8 Note 4	
8. Quality: Not specified	
9. Precursors: See composition	
10. Precursor Quality: Not specified	
11. Production Process: Not specified	
12. Production Equipment: Not specified	
13. U.S. Producers: Unknown	
14. Production Capacity: Unknown	**15. Cost:** Not applicable
16. Shipping Pack & Label: UN Hazard class 4.2, when mixed	
17. Color & Form: Oily liquid	
18. Foreign Producers: Unknown	
19. Foreign Capacities: Unknown	
20. Military Uses: Used to prepare Napalm; mixed in gasoline at 16-29°C to form a gel.	

21.	**Civil Uses:** None
22.	**Notes:** See notes for military fuel thickeners.
23.	**References/MILSPECS:** MIL-T-589A

1. Substance or Composition: M2 thickener	**3. Molecular Structure:** Not applicable
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:

6. Chemical Composition:
95% M1 thickener, 5% devolatilized silica gel

7. Control Status:
Controlled by ML-8 Note 4

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Not specified

12. Production Equipment:
Not specified

13. U.S. Producers:
Unknown

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 4.2, when mixed

17. Color & Form:
Oily liquid

18. Foreign Producers:
Unknown

19. Foreign Capacities:
Unknown

20. Military Uses:
USAF incendiary oil thickener; used in preference to M1 alone to provide a free flowing, faster setting composition, and a more stable gel in bombs.

21.	**Civil Uses:** None
22.	**Notes:** See notes for military fuel thickeners.
23.	**References/MILSPECS:** MIL-T-13025C MIL-T-0013025B

1. Substance or Composition: M4 thickener	**3. Molecular Structure:** Not applicable
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:

6. Chemical Composition:
Diacid Al soap of isooctanoic acids, with 2% Santocel C or Attclay SF as anticoagulants.

7. Control Status:
Controlled by ML-8 Note 4

8. Quality:
Not specified

9. Precursors:
By-product of petroleum

10. Precursor Quality:
Not specified

11. Production Process:
Not specified

12. Production Equipment:
Not specified

13. U.S. Producers:
Unknown

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 4.2, when mixed.

17. Color & Form:
Oily liquid

18. Foreign Producers:
Unknown

19. Foreign Capacities:
Unknown

20. Military Uses:
A faster mixing, less diluting thickener than M1 giving a more homogeneous product for flame throwers and consequent improved range and effectiveness.

21.	**Civil Uses:** None
22.	**Notes:** See notes for military fuel thickeners.
23.	**References/MILSPECS:** MIL-T-50009A

1. Substance or Composition:
Magnesium

2. CAS Registry No.:
7439-95-4

3. Molecular Structure:

Not applicable

4. Acronym(s) or Trade Designation(s):

5. Synonyms:

6. Chemical Composition:
Mg

7. Control Status:
a. Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR
b. Controlled by MTCR

8. Quality:
a. Powders in particle sizes <60 micro-meters whether spherical, atomized, spheroidal, flaked, [sponge], or ground; (ML, USML)
b. Particle sizes <500 micro-meters, whether spherical, atomized, spheroidal, flaked, or ground consisting of 97% by weight or more of Mg (MTCR)

9. Precursors:
Magnesium stock/ingots

10. Precursor Quality:
a. 99% or greater purity
b. 97% or greater purity

11. Production Process:
a. Atomizer to produce spherical grain; mechanical grinding to produce flake or ellipsoidal grains
b. Mechanical grinding

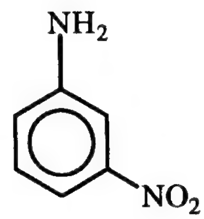
12. Production Equipment:
a. Nitrogen or inert gas atomizer; rapid-cooling plant to produce spherical grains; or air-atmosphere grinding mills

13. U.S. Producers:
Reade Mfg. Co.,
100 Ridgeway Blvd.,
Lakenhurst NJ 08733.
Tel: (908) 657-6451;
FAX: (908) 657-6628.
Contact Mr. Bruce Gwynne, VP Sales;
Hart Chemical;
TRACOR Aerospace P.O. Box 196, San Ramon 94583-0196

14. Production Capacity:
Unknown

15. Cost:
a. $10-20 per lb
b. $7-15 per lb

16.	**Shipping Pack & Label:** UN Hazard Class 4.3; shipped in unlined 55 lb. barrels or 150 lb./30 gal. steel drums
17.	**Color & Form:** Gray powder
18.	**Foreign Producers:** Capabilities may not cover finer or spherical grades: Korea; Japan; China; Italy Germany, at least two plants; UK at least two plants
19.	**Foreign Capacities:** Significant
20.	**Military Uses:** a. nfrared missile decoys b. Decoys and tracer ammunition
21.	**Civil Uses:** Metal alloys
22.	**Notes:** Grinding of the fine powder requires a lot of control; explosions occur, though not as commonly as with the atomizer approach. MIL SPEC material falls nominally into several types, grades and granulations: Type I Flaked and/or chipped Grade A(96% min. Mg content) Grade B(86% min.. Mg content); Type II Oblong chips with rounded edges (96% min. Mg content); Type III Atomized (98% min. Mg content); Type IV Flaked and/or chipped (95.5% min. Mg content); There are several granulations with nominal mesh sizes in the 30 down to 525 range, but these tend to date back 20-30 years and not reflect modern capabilities and requirements for precision decoy rise times. Types I (grade A), II, and II are required to be manufactured from 99.8% Mg stock. Type I grade B (stock purity not specified) and Type IV from 95.5% Mg stock are not covered by the control parameters. Coarser powders tend not to have a military application, except as a source of finer powder.
23.	**References/MILSPECS:** MIL-M-382C(AR)

1. Substance or Composition: Meta-nitroaniline	**3. Molecular Structure:** 
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s): m-MNA	

5. Synonyms:
3-nitroaniline;
3-mononitroanaline;
1-nitro-3-aminobenzene

6. Chemical Composition:
$O_2NC_6H_4NH_2$; or $C_6H_6N_2O_2$

7. Control Status:
None; listed in 1992 MCTL

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Not specified

12. Production Equipment:
Not specified

13. U.S. Producers:
Unknown

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label:
Unknown

17. Color & Form:
Yellow rhomb. needles.

18.	**Foreign Producers:** Sweden?
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Precursor for the manufacture of ADNBF
21.	**Civil Uses:** Unknown
22.	**Notes:** The United States is the only confirmed source for this precursor, but it is not unlikely that Sweden also makes it.
23.	**References/MILSPECS:** MIL-STD-1213A

1. Substance or Composition: Military fuel thickeners	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: Not registerable	
4 Acronym(s) or Trade Designation(s): Octal(qv) Napalm	

5. Synonyms:
Compounds (e.g. octal) or mixtures of compounds (e.g. napalm) specifically formulated to produce materials which when added to petroleum products provide a gel-type incendiary for use in bombs, projectiles, flame throwers. Popularly called "Napalm".

6. Chemical Composition:
See entries for Octal. M1, M2, M4 thickeners.

7. Control Status:
Controlled by ML-8 Note 4; USML CAT V §121.13

8. Quality:
Not specified

9. Precursors:
Stearic, oleic, and various organic acids.

10. Precursor Quality:
Not specified

11. Production Process:
Propritary

12. Production Equipment:
Propritary

13. U.S. Producers:
Unknown

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label:
Unknown

17. Color & Form:
Not applicable

18. Foreign Producers:
Unknown

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Napalm and flame-thrower gelling agents.
21.	**Civil Uses:** See notes.
22.	**Notes:** Octal, not to be confused with Octol (an HMX-TNT formulation), is an acronym for aluminum stearate, also known as aluminum octadecanoate (qv), a salt of octadecanoic acid. The M1, M2, etc., thickeners are also blends of stearic acid and palmitic acid (the hexa analog of octadecanoic acid). They are derived from natural animal and vegetable fats, including the fermented pulp of palm trees. In recent decades increasingly pure and refined grades of these substances have become available due to their widespread use for pharmaceuticals, cosmetics, soaps, and food packaging, not to mention waterproofing leather and textiles, and industrial dispersion and softening agents. It is unlikely that today's products could be readily substituted for the commercial products that were available during World War II for use with flame agents, even supposing the *ad hoc* formularies and processes were still available to the pyrotechnics community.
23.	**References/MILSPECS:**

1. Substance or Composition:
Mixed nitrous oxide-nitrogen tetroxide (see notes)

2. CAS Registry No.:
Probably not registrable

3. Molecular Structure:
Not applicable

4. Acronym(s) or Trade Designation(s):
MON

5. Synonyms:

6. Chemical Composition:
Typical compositions are: 3% NO-N_2O_4;
10% NO-N_2O_4;
25% NO-N_2O_4

7. Control Status:
Controlled by MTCR?

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Not specified

12. Production Equipment:
Not specified

13. U.S. Producers:
Manufacturers of nitric acid; particularly manufacturers of nitrogen fertilizers

14. Production Capacity:
Significant

15. Cost:
NAS

16. Shipping Pack & Label:
UN Hazard Class 2.3, toxic gas; secondarily Class 5.1, oxidizing substance, and Class 8 corrosive substance.

17. Color & Form:
Shipped under pressure as a liquid

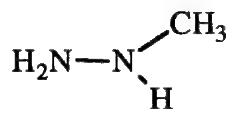
18. Foreign Producers:
Widely available

19. Foreign Capacities: Unknown	
20. Military Uses: Under consideration for upper stages of THAAD.	
21. Civil Uses: Unknown	
22. Notes: Proposed for control as mixed nitrous oxide-nitrogen tetroxide; it has been suggested that the entry should read "mixed oxides of nitrogen" or "nitric" rather than nitrous oxide. Nitrous oxide, N_2O (Nitrogen monoxide or laughing gas), is a colorless, non-combustible gas, used as an anæsthetic and occasionally as a propellant for food aerosols. The data above presume that nitric oxide was intended.	
23. References/MILSPECS: AIA/NAS NAS 3260	

1. Substance or Composition:
Monomethyl hydrazine

2. CAS Registry No.:
60-34-4

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
MMH

5. Synonyms:

6. Chemical Composition:
CH_3NHNH_2; or CH_6N_2

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9. Precursors:
Monomethyl amine

10. Precursor Quality:
Not specified

11. Production Process:
Similar to process for UDMH (qv)

12. Production Equipment:

13. U.S. Producers:
Olin Corp.,
Cheshire CT.
Tel: (203) 356-4071.
Dr. Karl Seefried, VP Technology

14. Production Capacity:

15. Cost:

16. Shipping Pack & Label:
UN Hazard Class 6.1, toxic substance; subsidiary risk Class 3, flammable liquid; and Class 8, corrosive substance.

17. Color & Form:
Liquid

18. Foreign Producers:
France (SNPE)

19.	**Foreign Capacities:** Significant
20.	**Military Uses:** Missile propellant fuels: MHF-3, MHF-5, MHF-6
21.	**Civil Uses:** Commercial launch vehicles; Pharmaceutical?
22.	**Notes:**
23.	**References/MILSPECS:** MIL 27404-B MIL-P-81507 MIL-P-81342 MIL-P-81726

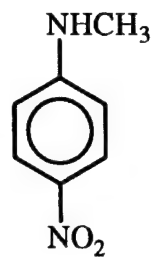
1. Substance or Composition: N-butyl-ferrocene	**3. Molecular Structure:**
2. CAS Registry No.: 31904-29-7	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms:	
6. Chemical Composition:	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12; MTCR.	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Not specified	
12. Production Equipment: Not specified	
13. U.S. Producers: Unknown	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label: Not specified	
17. Color & Form: Liquid	
18. Foreign Producers Germany?	
19. Foreign Capacities: Unknown	
20. Military Uses: Burn rate modifier and smoke reducer for solid propellants.	

21.	**Civil Uses:** Unknown
22.	**Notes:** Specific, listed ferrocene derivative.
23.	**References/MILSPECS:**

1. Substance or Composition:
N-methyl-4-nitroaniline

2. CAS Registry No.:
100-15-2

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
NMNA
pNMA

5. Synonyms:
N-methyl-p-nitroaniline;
p-nitro-N-methylaniline

6. Chemical Composition:
$C_7H_8N_2O_2$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9. Precursors:
methylaniline, chloronitrobenzene, methyliodide, methylsulfate, nitroaniline

10. Precursor Quality:
Not specified

11. Production Process:
Not specified

12. Production Equipment:
Not specified

13. U.S. Producers:
Unknown

14. Production Capacity:
Unknown

15. Cost:
Not available

16. Shipping Pack & Label:

17. Color & Form:
Yellow needles

18. Foreign Producers:
UK

19. Foreign Capacities:

20. Military Uses:
Plasticizer and stabilizer with n-ethyl analog for NC propellants

21. Civil Uses:

22. Notes:
This substance, also known as p-nitro-N-methylaniline, pNMA, is the sole remaining NC stabilizer listed in the ML, USML; the MTCR also lists 2-nitrodiphenylamine, 2-NDPA. pNMA was retained at the request of U.S. industry, because its advantages for use as a stabilizer were learned from a classified UK report. However, nitro-N-methylanilines have been prepared from the early 1900s, and it has been known since the 1950s that 4-nitro-N-methylaniline is superior to centralites and akardites in stabilizing NC. Although presumably easily made by the FSU using the indicated reactants (which are available to them), they are not known to use it; nor is any other country except the U.S. and UK. Sweden has the potential to manufacture the material, and India has investigated its use in composite modified double base propellants; the source of the Indian materials is not known.

The requirement for stabilizers is most pervasive when considering nitrocellulose-based compositions because NC's slow decomposition and self heating at ambient temperatures lead to runaway reactions and explosions in stockpiles. The phenomenon may occur even in the presence of stabilizers once they have themselves become consumed by reaction with decomposition products during storage. Developed nations maintain round-the-clock surveillance programs to check continuously the condition of ammunition stockpiles and avoid mass explosions. Cases are known, however, of less conscientious attention being given to such possibilities in civil agencies or in countries where ignorance, cost constraints, or demands for immediate use of products have led to the omission of stabilizers. The total destruction of a Finnish ammunition facility in the 1970s is but one example of the potential consequences.

Dual stabilizer systems are also widely used for cast double base propellants as they help to promote a crack-free life of the propellants during storage. The second stabilizer is usually 2-NDPA or 4-NDPA, amines deleted from the ML and MCTL. The assumption has been that the secondary amine reacts more slowly and independently in the period following depletion of the first stabilizer. However, it has recently been reported by the UK (Ref. 1) that in the early stages the efficiency of 4-NDPA in reducing 2-NDPA depletion is better than pNMA, but lower than that shown by resorcinol alone or in combination with pNMA; 4-NDPA with 2-NDPA is a better combination than pNMA with 2-NDPA for cast double base propellants. So the technical basis for continuing to list pNMA is probably moot. Moreover, one of the authors of the paper was from the Ministry of Defense Armament Authority in Cairo, Egypt. So the technology for pNMA is probably widely known and understood outside of the United States.

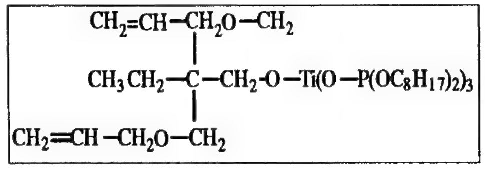
23. References/MILSPECS:

1. Bellamy, A. J., M. H. Sammour, and J. M. Bellerby, *Propellants, Explosives, Pyrotechnics* 1993, 18, 223–229.

1. Substance or Composition:
Neopentyl (diallyl) oxy, tri(dioctyl) phosphato titanate

2. CAS Registry No.:
110438-25-0, or 103850-22-2 (See notes)

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
Ken-React LICA 12; or
LICA 12

5. Synonyms:
Titanium IV [2,2-(bis-2-propenolatomethyl) butanolato, tris(dioctyl) phosphato-O"]; or,
Titanium, tris[bis(2-ethylhexyl)phosphato-O"][2,2-bis[(2-propenyloxy)methyl]-1-butanolato-O,O',O"];
(See also Notes)

6. Chemical Composition:

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Contains 5% Isopropyl alcohol (CAS 67-63-0)/Isooctyl alcohol (26952-21-6)

9. Precursors:
Octyl phosphoric acid, or 2-ethylhexynol and P_2O_5;
Alkyl-propyl trimethylol propane

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Kenrich Petrochemicals, Inc. 140 E. 22nd St., Bayonne NJ 07002-0032.
Tel: 201-823-9000; Fax 201-823-0691.
POC: Mr. Sal. Monte, President

14. Production Capacity:
Unknown

15. Cost:
$8.00/lb

16. Shipping Pack & Label:
Tightly-sealed container, UN Class 3 ; US Class IIIA, flammable liquid.

17.	**Color & Form:** Orange liquid (Gardner 4-8)
18.	**Foreign Producers:** None
19.	**Foreign Capacities:** None
20.	**Military Uses:** Coupling agent, adhesion promoter, catalyst, etc. for plastic (polymer bonded propellant and high explosive compositions
21.	**Civil Uses:** Potential additive for commercial, impact resistant polymers requiring hydrophobic, organophilic properties
22.	**Notes:** The entry in the USML needs editing. A neoalkoxy titanate, LICA 12 has two CAS nos. because it can be made by two routes using one or the other of the precursors listed. Other names for the products are: phosphoric acid, dioctyl ester, titanium complex; 1-butanol, 2,2-bis[2-propenyloxy) methyl],titanium complex; phosphoric acid, bis(2-ethylhexyl)ester, titanium complex. The manufacturer assigns the first of the listed nos. to its product (known by the trade names LICA-12, etc), a substance with six straight chain octyl groups. CAS assigns the trade names LICA-12 and Ken-React-12 to the second number; i.e. to a substance that includes six 2-ethylhexyl groups. The company says there is little difference in the performance of the products for the listed applications.
23.	**References/MILSPECS:**

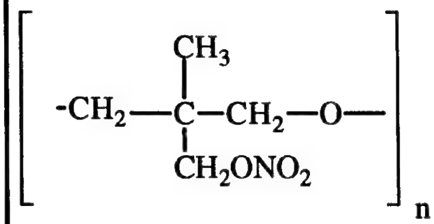
1. Substance or Composition: Nickel-aluminum active metals	**3. Molecular Structure:** Not available
2. CAS Registry No.: None	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms:	
6. Chemical Composition: Classified	
7. Control Status: Not controlled; but substances of interest.	
8. Quality: Pyrophoric surfaces on metal or polymeric foils.	
9. Precursors: Proprietary alloys and materials employed.	
10. Precursor Quality: Not specified	
11. Production Process: Deposition of a slurry of pyrophoric alloy ingredients on a continuous coil or substrate, The coil is then passed through a controlled atmosphere furnace to form an intermetallic compound on its surface. Alternatively, a rapid diffusion process is used to introduce constituents into the base metal. in either case selective removal of elements leaves a highly reactive, porous material, which must then be protected from contact with oxygen until called upon to function in a decoy device.	
12. Production Equipment: No unique equipment.	
13. U.S. Producers: Alloy Surfaces Co., 100 Locke Road, Wilmington DE 19809 Mr. L. Stephen Bowers, President; Dr. John A. Lafemina, VP R&D Tel: (302) 762-8900; FAX: (302) 762-7213	
14. Production Capacity: Significant; sufficient to produce 1000 units per month.	**15. Cost:** Approx. $90.00 per decoy round.
16. Shipping Pack & Label: The products are UN Hazard Class 4.2 pyrophoric substances. They are sealed in an inert gas and packaged as a Class 4.2 articles, namely as a decoy system components.	

17.	**Color & Form:** Dark grey metallic wires, strips, and foils.
18.	**Foreign Producers:** None
19.	**Foreign Capacities:** None
20.	**Military Uses:** Smart munition decoys; for example MJU 27B system.
21.	**Civil Uses:** None
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition:
Nitratomethylmethyloxetane

2. CAS Registry No.:
84051-81-0

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
NMMO or poly-NIMMO; BNMO

5. Synonyms:
poly-(3-nitratomethyl, 3-methyl oxetane);
bis(nitratomethyl)oxetane

6. Chemical Composition:
$C_5H_9NO_4$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Bischloromethyloxetane

10. Precursor Quality:
Not specified

11. Production Process:
N_2O_5 nitration process; Desmodur N100 curing agent with dibutyl tin dilaurate(DBTDL) as a catalyst.

12. Production Equipment:
Not specified

13. U.S. Producers:
Unknown

14. Production Capacity:
Unknown

15. Cost:
Not available

16. Shipping Pack & Label:
Not specified

17. Color & Form:
Not specified

18. Foreign Producers:
ICI Explosives, Nobel's Explosive Co. Ltd., Stevenston, Ayrsh., Scotland KA20 3LN
Asahi Chemical Industry Co., Japan?

19. Foreign Capacities:
Pilot plant quantities.

20. Military Uses:
Energetic binder for low vulnerability propellants; and for high energy propellants such as Boron compositions

21. Civil Uses:
None

22. Notes:
NMMO or poly-NIMMO and azido-methyl-methyl-oxetane (AMMO) are intended for use with nitrates of polyhydric alcohols (PEG, PEP, TMETN, BTTN, etc.) or oxetane alcohol monomers for new medium energy propellants, or with NG for high energy propellants. A pilot plant for the manufacture of poly-NIMMO has been developed by ICI Explosives in a joint development with the UK Ministry of Defence.(Ref. 1) The energetic liquid polymer is cured using isocyanates, yielding both di- and tri-functional versions that are miscible with energetic plasticizers. The binder is a candidate for incorporation in EMDBP.

23. References/MILSPECS:

1. D. Debenham, W. H. Leeming, E. J. Marshall. *Proceedings of 21st. International Conference of Fraunhofer Institute of Chemical Technologie*, Karlsruhe, Germany 1990, p. 53-1.

1. Substance or Composition: Nitrocellulose	**3. Molecular Structure:** See composition
2. CAS Registry No.: 9004-70-0. Generally, not stoichiometric compound(s)	
4. Acronym(s) or Trade Designation(s): NC	

5. Synonyms:
Cellulose nitrates (approx. 9 variants); US/foreign examples include: Collodion; Coton-poudre, Pyroxyline(Fr); Nitozellulose(Ger); Nitrocellosa(It); Nitrokletchatka, Piroksilin, Nitrotsellulosa(Rus); Piroxilina(Sp); Shokamen(Jap).

6. Chemical Composition:
Ranges from $C_{24}H_{28}O_8(ONO_2)_{12}$ to $C_{24}H_{36}O_{16}(ONO_2)_4$;
$C_{12}H_{14}N_6O_{22}$, corresponding to 14.14% N content; highest laboratory grade has about 13.4%N.

7. Control Status:
a. Former USML CAT V §121.12
b. ML-8, Grades with N content >12.4% de-controlled; lower grades never controlled.

8. Quality:
a. Nitrogen content >12.2% (former USML);
b. >12.4% nitrogen content (former ML)

9. Precursors:
Cotton linters; wood pulp

10. Precursor Quality:
Not specified

11. Production Process:
Nitration of cellulose with mixed $HNO_3.H_2SO_4$

12. Production Equipment:

13. U.S. Producers:
Hercules; Radford AAP, VA

14. Production Capacity: Significant	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 1.1D explosive, dry or wetted with <25% water/alcohol by weight; Class 1.3C explosive, wetted with >25% water/alcohol by weight; Class 4.1, flammable solid, generally when <12.6% nitrogen content.

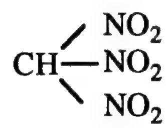
17. Color & Form:
Pale yellow, syrupy liquid

18.	**Foreign Producers:** All NATO countries, Japan, Russia, Sweden, and a wide range of developed and developing countries
19.	**Foreign Capacities:** Significant
20.	**Military Uses:** Gun and rocket propellants
21.	**Civil Uses:** Paints, varnishes; civil gun propellants civil dynamites, pharmaceuticals, photographic products.
22.	**Notes:** There are five principal military grades of NC, with different types within each grade; but only three of these (grades A, B and C) meet the former >12.4% nitrogen control limits.
23.	**References/MILSPECS:** MIL-N-244A

1. Substance or Composition:
Nitroform

2. CAS Registry No.:
517-25-9

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
TNM;
TNMe

5. Synonyms:
Trinitromethane

6. Chemical Composition:
CHN_3O_6

7. Control Status:
Not controlled, but a key precursor for advanced military explosive ingredients.

8. Quality:
Not specified

9. Precursors:
Acetic anhydride; tetranitromethane (US process). Or acetylene-nitric acid for Swedish process; or nitric acid and malonamide.

10. Precursor Quality:
Not specified

11. Production Process:
Non-acetylene process (US)

12. Production Equipment:
Proprietary

13. U.S. Producers:
GenCorp

14. Production Capacity:
Limited, subject to demand

15. Cost:
Not available

16. Shipping Pack & Label:
Toxic substance

17. Color & Form:
A colorless to pale yellow solid , or a yellow oily liquid (mp 26.1°C)

18. Foreign Producers:
Sweden;
CH?

19. Foreign Capacities:
Unknown

20. Military Uses:
Preparation of explosives.

21. Civil Uses:

22. Notes:
Also known as trinitromethane, nitroform is made in the U.S. only from acetic anhydride with tetranitromethane as an intermediate, i.e., by a non-acetylene process that was developed and patented in the U.S. Sweden developed a acetylene-nitric acid process that was previously used in the U.S., but this process proved to have safety problems. Available information now indicates that Sweden continues to be the only supplier for the acetylene process; however, because of an explosion that destroyed the facility in Sweden, the process is not allowed to be used there. CH may also have a plant for making nitroform, but the source of the plant or of this precursor for making ZOX (or bis(2,2,2-trinitroethyl-N-nitro)ethylene diamine) is not known. Since the FSU first prepared ZOX, it is probable that they also make nitroform, but also by an acetylene method.

23. References/MILSPECS:

1. Substance or Composition: Nitrogen dioxide	**3. Molecular Structure:**
2. CAS Registry No.: 10544-72-6	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms: Dinitrogen tetroxide; Nitrogen peroxide Nitrogen tetroxide	
6. Chemical Composition: NO_2; N_2O_4	
7. Control Status: Controlled by USML CAT V §121.14; MTCR	
8. Quality: Not specified	
9. Precursors: Ammonia; nitric oxide	
10. Precursor Quality:	
11. Production Process: Oxidation of nitric oxide, an intermediate in the oxidation of ammonia to nitric acid	
12. Production Equipment:	
13. U.S. Producers: Manufacturers of nitric acid; particularly manufacturers of nitrogen fertilizers	
14. Production Capacity: Very large, subject to demand	**15. Cost:**
16. Shipping Pack & Label: UN Hazard Class 2.3, toxic gas; secondarily Class 5.1, oxidizing substance, and Class 8 corrosive substance.[200 ppm in air may be fatal]. Shipped in 125, 150, and 2000 lb cylinders and in tank cars.	
17. Color & Form: Reddish brown gas at 20°C with a pungent odor; yellow liquid, or orange red liquid <9.1°C (see notes); colorless solid at -11.2°C.	
18. Foreign Producers: FSU, China, India, France, UK, Germany , Japan, etc.	
19. Foreign Capacities: Significant	

20. Military Uses:
Planned for upper stages of THAAD air defense missile, otherwise used for strategic missiles

21. Civil Uses:
Commercial space launch vehicles; space vehicle thrusters; dye manufacture. Also used to produce nitric acid, as a nitrating or oxidizing agent, and used as a polymerization inhibitor for acrylates.

22. Notes:
This substance, also known as nitrogen peroxide, is widely used with hydrazine, nitric acid, and UDMH or with MMH in the shuttle, the launch or post-boost stage of ballistic missiles (Titan, Delta, Peacekeeper, for example), and in apogee and maneuvering thrusters for satellites that use bi- rather than mono-propellants(hydrazine). It is used by CH in the FB-1 (CSL-2); by France in the Ariane with UH25; by India in ballistic missiles under development; by Japan with Aerozine 50; and the FSU in the Salyut launcher-13 and probably several other systems. NO_2 vaporizes (boils) at 21° and is a powerful agent that reacts explosively with numerous common fuels. The equilibrium, $2NO_2 = N_2O_4$, tends to the right at low (ambient) temperatures; hence the name nitrogen tetroxide is also often used.

When heated, reddish brown N_2O_4 becomes paler because of the dissociation to $2NO_2$ and finally colorless because of decomposition to NO and O. When cooled it becomes dark orange-red liquid which solidifies at -11.2°C to a nearly colorless solid N_2O_4.

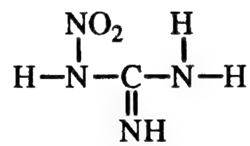
Its transportation is restricted for safety reasons in the United States, which is probably more lenient in this regard than some countries. It is prepared industrially from nitric acid and air, and can be produced by almost any plant engaged in ammonium nitrate (AN) production. AN is produced in very large quantities (billions of pounds per annum) for fertilizers and commercial explosives, in the United States, Canada, FSU, CH, India, and numerous other industrial countries. N_2O_4 also is used commercially for manufacturing dyes and other nitration reactions. Its omission from ML 8 was recommended because embargo would probably be infeasible and/or ineffective and as appropriately handled under the IIL as the ML, if at all justified. (Note that AN is not embargoed.)

23. References/MILSPECS:

1. Substance or Composition:
Nitroguanidine

2. CAS Registry No.:
556-88-7

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
NQ;
NGu
Picrite
Gudol (Germany)

5. Synonyms:

6. Chemical Composition:
$CH_4N_4O_2$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; USML CAT V §121.14

8. Quality:
None specified; but high-density, or spherical NQ are of particular concern (See Notes)

9. Precursors:
Guanidine nitrate, and sulfuric acid

10. Precursor Quality:
None specified

11. Production Process:
Continuous and batch processes (See Notes).

12. Production Equipment:

13. U.S. Producers:
Sunflower Army Ammunition Plant

14. Production Capacity:
Potential: 22.4 million lb per month (122,000 metric tonnes per year);
Actual(1990): 700,000 lb per month (3818 metric tonnes per year)

15. Cost:
$4.00 per lb

16. Shipping Pack & Label:
UN Hazard Class 1.1, if dry or wetted with less than 20% water by weight; packed in wooden, fiber, or steel boxes, barrels, or drums; with plastic or paper bag or sheet liners.
UN Class 4.1 with not less than 20% water by weight at all times.

17. Color & Form:
White, fiber-like crystals; but may be in form of cubic or 'spherical' crystals

18. Foreign Producers:
Canadian Industries Ltd, Canada;
Royal Ordnance, Bridgewater, UK;
Dynamit Nobel, Troisdorf, Germany;
Institut für Treib- and Explosivstoffe (ICT), Pfinztal-Berghausen, Germany;
NIGU Chemie GmbH, Germany
Italy, Colleferro;
FSU;
Nobel Explosives, Sweden;
Somerchem Pty, Somerset, South Africa;
Australia.
(See Notes).

19. Foreign Capacities:

20. Military Uses:
Ingredient of triple base gun propellants, and missile propellants; experimental fill for insensitive high explosive charges.

21. Civil Uses:
None, or very limited

22. Notes:
Within NATO NQ is prepared by dissolving guanidine nitrate in concentrated sulfuric acid and precipitating the product as long, flexible needles, which are difficult to pulverize. Drawing on Canadian and UK technology, the U.S. Army at Sunflower Army Ammunition Plant has developed a continuous process for the manufacture of NQ, but not without difficulty because of the interference of the needles in the flow process.

In addition to the Canadian and UK facilities, batch processes for NQ exist in Germany (Dynamit Nobel, Troisdorf) and Italy (Colleferro). Currently, NATO countries (including the U.S.) are advancing the manufacturing technology to achieve improved, pollution-free processes and to develop the new grades of material suitable for both advanced propellants and less sensitive high explosives. In this respect, the U.S. is most interested in protecting the manufacturing technology and availability of high-density, or spherical NQ, as such grades eliminate the problems encountered with needles and facilitate the blending of NQ with other ingredients of compositions.

The Institut für Treib- and Explosivstoffe (ICT), Pfinztal-Berghausen, Germany, developed a small-scale manufacturing process for NQ in a spherical, granular form, and has been actively seeking foreign licenses for the process. The U.S. Sunflower AAP also produces a higher density form. A high density form manufactured by NIGU Chemie GmbH is also offered for sale by SKW Chemicals of Marietta, GA.

The German-quality material is used in the 27-mm gun system (analogue of the U.S. 30-mm GAU-8) in the Tornado aircraft. Dynamit Nobel, Troisdorf, makes the spherical NQ from an indigenous source of guanidine nitrate (GN). The Sunflower AAP in Kansas will probably be the only other supplier of this quality material, unless the technology has already been licensed to South Africa by Germany.
(Cont.)

22. Notes (Cont.):

Because the Albion Explosives Factory has advertised triple-base propellants among its product range, it must be concluded that Australia had access to NQ supplies. Australia's explosives production capability drew heavily on UK resources in the past. Britain, Canada, or the U.S. are the probable sources of their stocks. More recently, however, Australia was developing its own manufacturing capability and evaluating options in the design of the plant. A first step in the process will be the adoption of a process for the precursor guanidine nitrate(qv). Acid facilities to convert GN to NQ already exist. Adequate support is available from the adjacent plant of Imperial Chemical Industries of Australia and New Zealand; access to the latest U.S., Canadian, and UK technology is available through Mutual Weapons Development Data Exchange Agreements and the Technical Cooperation Program (Panel W). It must be concluded, therefore, that Australia has a capability on hand that could develop into a superior capability.

Nitroguanidine propellants composited with diethylene glycol dinitrate, nitrocellulose, and other substances were developed in Germany before the war and used during World War II on the Russian Front. Their advantages should be known to the FSU from that experience. In fact, the FSU and former Warsaw countries used NQ in both high explosive and propellant compositions during World War II. Typically, however, the former Warsaw Pact countries do not produce the triple-base propellants used in the U.S., UK, and Germany. In part, this has been because an alternative substance, diethylolnitramine dinitrate or di(b-nitroxylethyl) nitramine (DINA), was available to them and obviated the need to rely on NQ. The FSU literature indicates that they have done as much research on NQ, and on its combustion, as any other country in the world. Such investigations of NQ do not require a large production capacity. It is believed that the FSU is endeavoring to develop a production capability, but it is not known whether they are encountering problems in fulfilling this objective, perhaps similar to those in the U.S.

Other non-NATO interest in nitroguanidine will develop as individual countries seek to meet demands for extended range artillery with acceptable erosion of gun barrels. The tendency will be for them (and the FSU/former Warsaw Pact countries) to adopt or improve on the UK/U.S. technology that was first introduced before and during World War II.

Until recently, developing countries were dependent solely on NATO countries for the technology and supplies of NQ or precursor substances. For example, South Korea imports NQ from Canada; Brazil, from Italy. NQ made at Colleferro, Italy, was also reported to have been exported to Libya (via Brazil). The products are fabricated into propellant charges and made available for export. However, several countries have begun to develop significant capabilities, which in one or two instances match or exceed U.S. capabilities. Once established (with NATO assistance), such technology is not likely to be passed uncontrolled to third parties; however, the products are included in munitions/ weapon systems which some countries specifically manufacture for export.

The non-NATO countries listed below have a significant capability to manufacture NQ. Details of their actual or proposed production capacities are not known.

Brazil. In the past, Brazil has imported NQ from Italy, but is now believed to import guanidine nitrate from Germany and manufacture its own nitroguanidine for triple base gun propellants. The extent of Brazil's knowledge of the German process is unknown; as are Brazil's intentions and timing for the construction of its own GN facility. Swedish or Swiss assistance could undoubtedly be obtained, as in the past for the construction of RDX facilities, if Brazil herself has not yet accrued sufficient expertise.

Israel. Israel is believed to have similar facilities to those at the Somerchem plant, South Africa.

South Africa. Drawing at least in part on German technology, South Africa has developed its own production base for NQ at Somerchem Pty, Somerset. It is reported to be based on an urea-ammonium nitrate process, not the modern British process. The quality of the product is high and is the basis for outstanding triple-base propellants for artillery projectiles. Somerchem Pty produces its own precursor GN.

23. References/MILSPECS:

1. MIL-N-494A
2. MIL-N-00494B

1. Substance or Composition: Nonanitroterphenyl	**3. Molecular Structure:** Not available
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s): NONA	

5. Synonyms:
2,2',2",4,4',4",6,6',6"-nonanitroterphenyl

6. Chemical Composition:
$C_{18}H_5N_9O_{18}$

7. Control Status:
Not controlled; but a substance of interest.

8. Quality:
Not specified

9. Precursors:
Picryl chloride; dichlorotrinitrobenzene

10. Precursor Quality:
Not specified

11. Production Process:
Precursors reacted in presence of electrolytic copper dust (Ref. 1)

12. Production Equipment:

13. U.S. Producers:
U.S. Navy at NSWC, White Oak MD

14. Production Capacity: Limited	**15. Cost:** > $200 per lb.

16. Shipping Pack & Label:
No UN Hazard Class assigned; but nominally a Class 1.1 detonating explosive.

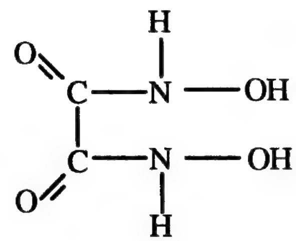
17. Color & Form:
Light yellow monoclinic crystals.

18. Foreign Producers:
None known

19. Foreign Capacities:
Unknown

20. Military Uses:
A thermally stable booster explosive for missiles; NONA has exceptional heat stability making it attractive as a booster explosive for space applications.

21.	**Civil Uses:** None
22.	**Notes:** Deserves consideration for control because it has had an explicit, although sensitive and limited, military application.
23.	**References/MILSPECS:** 1. J. C. Dacons, *Heat Resistant Explosives. VIII*, NAVORD Rept 6904 (1960) (Confid.)(Declass. 15 Jun 1972)

1. Substance or Composition: Oxalohydroxamic Acid	**3. Molecular Structure:** 
2. CAS Registry No.: 1687-60-1	
4. Acronym(s) or Trade Designation(s): DHG	

5. Synonyms:
Dihydroxyglyoxime;
Oxalohydroximic Acid

6. Chemical Composition:
$C_2H_4N_2O_4$

7. Control Status:
Not controlled, but of interest

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Not specified

12. Production Equipment:
Not specified

13. U.S. Producers:
Not determined

14. Production Capacity: Unknown	**15. Cost:** Not determined

16. Shipping Pack & Label:

17. Color & Form:
White crystal]

18.	**Foreign Producers:** Germany
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Propellant additive
21.	**Civil Uses:** Unknown
22.	**Notes:** Named as a substance of interest by Thiokol Corp., Elkton Div. 21 JUL 1994
23.	**References/MILSPECS:**

1. Substance or Composition: Oxy fluoride	**3. Molecular Structure:** Not available
2. CAS Registry No.: 12061-70-0	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms: Vague -a contraction of oxygen difluoride?
6. Chemical Composition:
7. Control Status: Controlled by ML-8 Note 1a; USML CAT V §121.21
8. Quality: Not specified
9. Precursors: Not specified
10. Precursor Quality: Not specified
11. Production Process: Not specified
12. Production Equipment: Not specified
13. U.S. Producers: Unknown

14. Production Capacity: Unknown	**15. Cost:** Not available

16. Shipping Pack & Label: UN Hazard Class 6.1
17. Color & Form: Liquid
18. Foreign Producers: Unknown
19. Foreign Capacities: Unknown
20. Military Uses: Not used in tactical missiles; occasionally used in strategic missiles

21.	**Civil Uses:**
22.	**Notes:** The entries in the control lists need to be clarified to reflect the intent
23.	**References/MILSPECS:**

1. **Substance or Composition:** Oxygen difluoride	3. **Molecular Structure:** See composition
2. **CAS Registry No.:**	
4. **Acronym(s) or Trade Designation(s):**	

5. **Synonyms:** Oxygen fluoride; Fluorine monoxide
6. **Chemical Composition:** OF_2
7. **Control Status:** Not explicitly controlled, but controlled by the generality of oxyfluoride (qv).
8. **Quality:** Not specified
9. **Precursors:** Not specified
10. **Precursor Quality:** Not specified
11. **Production Process:** Not specified
12. **Production Equipment:** Not specified
13. **U.S. Producers:** Unknown

14. **Production Capacity:** Unknown	15. **Cost:** Not available

16. **Shipping Pack & Label:** UN Hazard Class 2.3, toxic gas; secondarily Class 5.1, oxidizing substance, and Class 8, corrosive substance. Explodes in contact with air.
17. **Color & Form:** Colorless, unstable gas
18. **Foreign Producers:** Unknown
19. **Foreign Capacities:** Unknown

20.	**Military Uses:** Not used in tactical missiles; occasionally used in strategic missiles.
21.	**Civil Uses:**
22.	**Notes:** Oxy fluoride (oxygen difluoride) is an easily made, cryogenically storable, experimental oxidizer, if equipment to handle fluorine is available. There are severe toxicity and environmental problems associated with any prospective use. The U.S. could yield if there are other nation objections to its introduction into ML 8, as the substance is covered by the above general statement. It is similarly covered by the same statement in the MTCR.
23.	**References/MILSPECS:**

1. Substance or Composition: Pentaborane	**3. Molecular Structure:** See composition
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:
Pentaborane enneahydride

6. Chemical Composition:
B_5H_9

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Not specified

13. U.S. Producers:
Callery Chemical Co.,
Route 309,
Mars-Evans City Road,
Callery, PA 16024.
Contact: Ms. Beverly Jones.
Tel: (412) 967 4248
FAX: (412) 967-4270

14. Production Capacity: Limited	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 4.2, liable to spontaneous combustion; secondary risk 6.1, toxic substance.

17. Color & Form:
Colorless to yellow liquid

18. Foreign Producers:
Unknown

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Missile propellant
21.	**Civil Uses:** Unknown
22.	**Notes:** Specific boranes covered by existing boron hydride entries.
23.	**References/MILSPECS:** MIL-P-27403

1. Substance or Composition: Perchlorates, chlorates and chromatescomposited with powdered metal	**3. Molecular Structure:** Not available
2. CAS Registry No.: Not registrable	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:

6. Chemical Composition:
Not available

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR

8. Quality:
None specified

9. Precursors:
Individual perchlorates and pure metal powders.

10. Precursor Quality:
None specified

11. Production Process:
Grinding mixing and blending of ingredients

12. Production Equipment:
Explosion-proof milling and mixing machines; hydraulic presses.

13. U.S. Producers:
These mixtures are usually compounded by munitions developers prior to loading in particular devices. See references to particular perchlorates for prime producers of ingredients.

14. Production Capacity: Significant	**15. Cost:** Not available

16. Shipping Pack & Label:
Not normally shipped except as compounded charges in devices.

17. Color & Form:
White to gray solid compacts, depending on metal content

18. Foreign Producers:
Widely produced for standard pyrotechnic munitions.

19. Foreign Capacities:
Widely available in NATO countries and other countries that produce chlorate and perchlorates (see ammonium perchlorate).

20. Military Uses:
Conventional ordnance; missile propellant ignitors and ingredients of solid missile propellants and smoke compositions.

21. Civil Uses:
Solid propellants for commercial space-launch vehicles; fireworks.

22. Notes:
Perchlorates are oxidizing ingredients in solid missile and pyrotechnic compositions and may also serve independently as ingredients of high explosive compositions. In general, while imparting superior performance in comparison to the nitrates, they are less stable than the nitrates and require tighter control of processing variables for safety in handling, operational reliability, and fine tuning performance. Perchlorates also have advantages, including higher oxygen concentrations, in comparison with the chlorates and chromates.

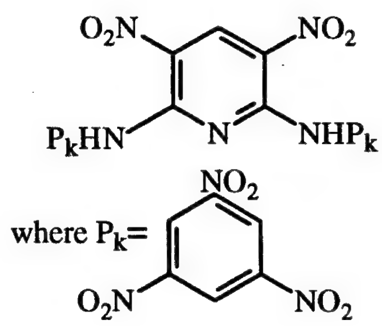
Although numerous inorganic perchlorates have been used in energetic materials, ammonium perchlorate (AP) is by far the most important. The potassium compound is also a significant ingredient of pyrotechnics, and sodium perchlorate is important as a precursor for AP.

As used in both pyrotechnics and propellants, the perchlorates, etc., commonly serve as oxidizers for the listed metal fuels, or they may be mixed with organic dyes to produce colored smokes or similar pyrotechnics. They may also be mixed with other, listed oxygen-deficient organic materials to increase their output.

23. References/MILSPECS:

1. Substance or Composition: Phenol-based antioxidants	**3. Molecular Structure:** Not available
2. CAS Registry No.: Not registrable	
4. Acronym(s) or Trade Designation(s): Series 2000, Protech™ antioxidants and stabilizers	
5. Synonyms:	
6. Chemical Composition: Not available	
7. Control Status: Controlled by USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Not specified	
13. U.S. Producers: MACH I Inc., 346 East Church Rd., King of Prussia PA19406; Tel: (215) 279-2340. POC: Bernard M. Kosowski, President	
14. Production Capacity: Limited	**15. Cost:** Not available
16. Shipping Pack & Label:	
17. Color & Form: Not determined	
18. Foreign Producers: Not determined	
19. Foreign Capacities: None	

20.	**Military Uses:**
21.	**Civil Uses:** None
22.	**Notes:** See notes for amine-based antioxidants.
23.	**References/MILSPECS:**

1. Substance or Composition: Picrylaminodinitropyridine	**3. Molecular Structure:** 
2. CAS Registry No.: 38082-89-2	
4. Acronym(s) or Trade Designation(s): PYX	

5. Synonyms:
2,6-bis(picrylamino)-3,5-dinitropyridine

6. Chemical Composition:
$C_{17}H_7N_{11}O_{16}$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
None specified; but the quality used for U.S. defense application

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Not specified

13. U.S. Producers:
Ensign Bickford Industries Inc.
660 Hopmeadow St.,
P.O. Box 427, Simsbury CT 06070-0427
Tel: (203) 843-2225
FAX:(203) 843-2621
Contact: Mr. Pete McGuinness

14. Production Capacity: Produces 3000–4000 lb./year up to 6000 lb./year; capacity is 30,000lb/year	**15. Cost:** $260-300/lb.

16.	**Shipping Pack & Label:** No UN Hazard Class assigned; but nominally a Class 1.1 explosive.
17.	**Color & Form:** Off-white crystals
18.	**Foreign Producers:** Bofors, Sweden (for U.S) China? (see Notes)
19.	**Foreign Capacities:** Probably > 6000 lb/year
20.	**Military Uses:** Used as a high temperature booster explosive in fuze trains.
21.	**Civil Uses:** Used for oil-well perforators .
22.	**Notes:** Chemtronics of Swananoa NC was the original maker of this material; but its plant was closed because of environmental concerns. The company was bought by Haliburton Corp. which has also since disposed of the company. The manufacturing process is very "dirty", which probably accounts for the following: CH has obtained a procedure for making PYX, but probably only in a crude form that is not usable by the U.S. defense industry; CH is possibly the only PYX manufacturer of this grade, which is possibly being purchased from CH by oil drilling companies. Ensign Bickford recrystallizes/purifies PYX into a form that is usable by the defense industry. Its source of crude PYX is not known. It is possible that PYX will replace HNS in some applications because of pollution problems also with the HNS process. A formulation known as LX-16 (PETN/ Vinyl polymer binder) is also a potential substitute for HNS in slapper applications.
23.	**References/MILSPECS:** MS 63208

1. Substance or Composition: Poly-[2,2,3,3,4,4-hexafluoro pentane-1,5-diol formal]	**3. Molecular Structure:** Not available
2. CAS Registry No.: More info. needed	
4. Acronym(s) or Trade Designation(s): FPF-1	

5. Synonyms:

6. Chemical Composition:
Not available

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Dichloroformals of nitroalcohols (e.g. polynitroalkyldichloroformals) reacted with nitrodiols

10. Precursor Quality:
Not specified

11. Production Process:
Classified ? See precurors above

12. Production Equipment:

13. U.S. Producers:
Energetic Materials Div.,
Naval Surface Warfare Center,
Indian Head MD 20640-5000
Tel: (301) 394-2477
AX (301) 394-4248
Contact: Ms. Dorothy Cichra.

14. Production Capacity: Laboratory, experimental quantities only	**15. Cost:** Not available

16. Shipping Pack & Label:
Not determined

17. Color & Form:
Not determined

18. Foreign Producers:
Italy?

19. Foreign Capacities:
Unknown

20. Military Uses:
Energetic binder for propellant or high explosive ingredients

21. Civil Uses:
Not determined

22. Notes:
FPF-1 and FPF-3 are energetic thermoplastic elastomers based on the fluoro dinitroacrylates. Non-energetic varieties of these are likely to be primarily commercial products. FSU capabilities are unknown, but in the late 1980s Eremenko in the FSU was reported to have published more on polynitroorthocarbonates than anyone else in the world.

The two listed polymers are particular examples of polynitroorthocarbonates or so-called Gilligan polymers. Current military interest in the materials is minimal because of practical problems in producing them, and in later NATO negotiations the U.S. recommended deleting them from ML-8. However, they, and FPF-1 and FPF-3 in particular, remain listed in ML-8; FPF-1 and FPF-3 are listed in the USML. It is questionable whether continued listing of any of the substances is justified; declassification action may be necessary to disembargo the substances cleanly.
Originally, the detailed chemical synthesis and identity of the precursors was classified, but the current classification has not been confirmed.

23. References/MILSPECS:

1. Substance or Composition: Poly-[2,4,4,5,5,6,6-heptafluoro-2-trifluoromethyl-3-oxaheptane-1,7-diol formal]	**3. Molecular Structure:** Not available
2. CAS Registry No.: More info. needed	
4. Acronym(s) or Trade Designation(s): FPF-3	
5. Synonyms:	
6. Chemical Composition: Not available	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Dichloroformals of nitroalcohols (e.g. polynitroalkyldichloroformals) reacted with nitrodiols	
10. Precursor Quality: Not specified	
11. Production Process: See precursors	
12. Production Equipment: Not specified	
13. U.S. Producers: Energetic Materials Div., Naval Surface Warfare Center, Indian Head MD 20640-5000 Tel: (301) 394-2477 FAX (301) 394-4248. Contact: Ms. Dorothy Cichra.	
14. Production Capacity: Laboratory, experimental quantities only	**15. Cost:** Not specified
16. Shipping Pack & Label: Not determined	
17. Color & Form: Not determined	
18. Foreign Producers: Italy?	

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Energetic binder for propellant or high explosive ingredients
21.	**Civil Uses:** Not determined
22.	**Notes:** See notes for FPF-1.
23.	**References/MILSPECS:**

1. Substance or Composition: Polybutadiene-acrylic acid	**3. Molecular Structure:** See composition
2. CAS Registry No.: 25067-26-9	
4. Acronym(s) or Trade Designation(s): PBAA	
5. Synonyms:	
6. Chemical Composition: CH_2: CHCN: CH_2	
7. Control Status: Controlled by MTCR (CAT 1.c.b.4)	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process Proprietary	
12. Production Equipment: Not specified	
13. U.S. Producers: Firestone Tire & Rubber Co. Phillips Petroleum Co.	
14. Production Capacity: Probably millions of tonnes per year.	**15. Cost:** Not available
16. Shipping Pack & Label: Drums, bankcars	
17. Color & Form: Colorless liquid	
18. Foreign Producers: Shell Oil Co., Europe; Bayer and IG Farben, Germany; Russia; Poland; India; China	
19. Foreign Capacities: Probably millions of tonnes per year.	

20. Military Uses:
Binder for rocket and missile propellants and high explosives.

21. Civil Uses:
Widely used throughout the world in synthetic rubbers, auto tires etc.

22. Notes:
This polymer, derived from 1,3-butadiene, has been so widely available for many years that it has not been listed explicitly in the USML or the ML. For 50 years its ability to form polymers was unknown, yet by 1982 there were only 21 organic chemicals whose production in the U.S. exceeded that of butadiene for use in polymers. In 1974, the year of largest production, butadiene was tenth in volume in the U.S., and about 1.7 million metric tonnes were produced.

Butadiene was first developed in Germany by Bayer and I.G. Farbenindustrie during the 1910–1920 period. It became available in the U.S. in pilot plant quantities in 1932. During World War II it was made in Germany by a Reppe synthesis from acetylene and formaldehyde, and in the FSU by a one-step Lebedev process from ethanol. Now butadiene is produced as a by- or co-product of ethylene production and derived from the steam cracking of naphtha. In 1983 the U.S. capacity for co-product butadiene was 1.36 million tonnes/year. For a long time butadiene has also been produced almost entirely in Western Europe and Japan as a co-product of naphtha cracking. There is now an over-capacity in Europe, so that imports play an important role in the U.S. market. While ethanol has been replaced by petroleum as a source of butadiene, it is believed still to be used in Poland and India.

Butadiene polymers are produced by anionic polymerization, using alkali metals as the catalyst. Sodium was used by the FSU on a large scale during World War II. Over time, however, it was found that the structure of the polymer was influenced by the alkali metal used. Lithium compounds give the highest cis and trans configurations (typically 35 and 52% respectively), while other alkalis give products in which the (sometimes less desirable) vinyl configuration predominates. The use of the higher alkalis is more expensive and hazardous. More advanced technology using organolithium catalysts was pioneered by the Firestone Tire and Rubber Co. in 1950, and this approach was followed up by the Phillips Petroleum Co. in the U.S. and by the Shell Oil Co. in Europe. Telechelic polymers, having two terminal functional groups on the polymer chains, with the molecular weight of the polymers limited to values less than 5000, retain the liquid properties required for blending with solid fillers, and permit the formulation of composite explosives that may be either cast, molded, or solvent extruded. Carbon dioxide is used as the terminator for carboxylterminated polymers; ethylene oxide can be used as the terminating agent for hydroxylterminated products. The latter are covered by patents of the E.I. Dupont de Nemours Co. and Phillips Petroleum. A similar process of the National Distillers and Chemical Co., UK, has also been patented.

Most of the butadiene products produced worldwide are used for elastomers and plastics. Copolymers of styrene and butadiene (SBR) are the most widely used synthetic rubbers in the world; butadiene-acrylonitrile (PBAN) copolymers also have widespread use where solvent and oil resistance is required. Homopolymers are used for the tread and sidewalls of automobile tires. Early applications of polybutadienes in missile propellants were based on PBAN. Made by the American Synthetic Rubber Co., it is used in the space shuttle propellant. In addition to the CTPB and HTPB polymers discussed in more detail below, CTPB with acrylic acid (PBAA), and carboxylated polybutadiene (HC) (carboxy groups randomly distributed along the chains, rather than terminal groups) have been used as liners or binders in rocket motors in, for example, the Space Shuttle and Minuteman. The sole source of such specialty products is Thiokol, which produces them for internal consumption in its missile applications departments. Generally, however, commercial applications have dominated the markets for polybutadienes.

23. References/MILSPECS:
MIL-P47105

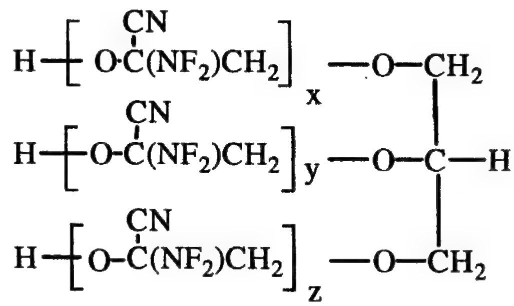
1. Substance or Composition: Polybutadiene acrylic acid- acrylonitrile **2. CAS Registry No.:** 25265-19-4 **4. Acronym(s) or Trade Designation(s):** PBAN (see also BNO)	**3. Molecular Structure:** See composition
5. Synonyms:	
6. Chemical Composition:	
7. Control Status: Controlled by MTCR (CAT 1.c.b.5)	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: Thiokol Corp., Science & Engineering, P.O. Box 707, MS 244, Brigham City UT 84302. Tel: (801) 863-2957; FAX: (801) 863-2271. Dr. Jerald C. Hinshaw.	
14. Production Capacity: See notes to PBAA	**15. Cost:** Not available
16. Shipping Pack & Label: Not determined	
17. Color & Form: Colorless liquid	
18. Foreign Producers: See notes to PBAA	

19.	**Foreign Capacities:** See notes to PBAA
20.	**Military Uses:** Binder for rocket and missile propellants and high explosives.
21.	**Civil Uses:** Widely used throughout the world in synthetic rubbers, auto tires etc.
22.	**Notes:** See notes to PBAA
23.	**References/MILSPECS:**

1. Substance or Composition:
Polycyanodifluoroamino-ethyleneoxide

2. CAS Registry No.:
Need more data

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
PCDE

5. Synonyms:

6. Chemical Composition:
$(C_3N_2F_2H_2O)_n$

7. Control Status:
Controlled by ML-8 Note 2.b; USML CAT V §121.12 b(2)

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Not specified

12. Production Equipment:
Not specified

13. U.S. Producers:
Fluor Corp?

14. Production Capacity:
Unknown

15. Cost:
Unknown

16. Shipping Pack & Label:
Unknown

17. Color & Form:
Unknown

18. Foreign Producers:
Unknown

19. Foreign Capacities:
Unknown

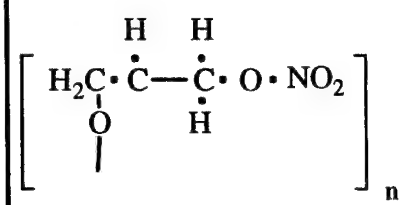
20. Military Uses:
See notes

21. Civil Uses:

22. Notes:
This controlled propellant ingredient is listed both in the ML-8 and USML §121.12, entry (b) 2. However, "It has been known since 1977 that PCDE would never make an acceptable propellant" (Ref. 1). There appears, therefore, to be some question whether this material should continue to be listed.

23. References/MILSPECS:

1. Stacer, R.G., in 21st International Annual Conference of ICT, 3–6 July 1990; Fraunhofer-Institute für Chemische Technologie, Karlsruhe, Germany, 1990, pp. 27–1 Annex.

1. Substance or Composition: Polyglycidyl nitrate	**3. Molecular Structure:** 
2. CAS Registry No.: 27814-48-8	
4. Acronym(s) or Trade Designation(s): PGN, or poly-GLYN	

5. Synonyms:
poly-(nitratomethyl oxirane);
also may be referred to as a polymer of glycide nitrate, of nitroglycide, or of the nitrate of epihydric alcohol

6. Chemical Composition:
$[H_5C_3NO_4]_n$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Glycidyl nitrate, ethylene glycol (chain propagating diol), boron trifluoride etherate (catalyst).

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
JPL, Aerojet, and Hercules have all had PGN based compositions under development since the 1950s. Source of the PGN is not determined.

14. Production Capacity: Not available	**15. Cost:** Not available

16. Shipping Pack & Label:
Monomer shipped as NG, being a high explosive only slightly less brisant.

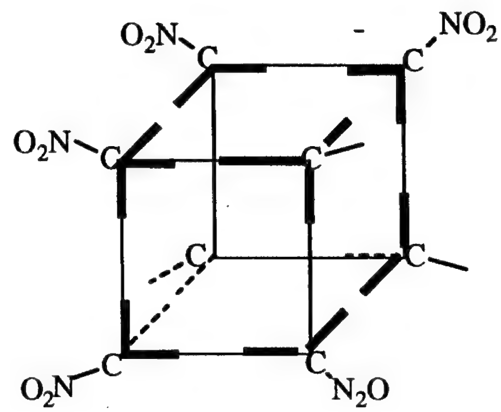
17. Color & Form:
The monomer is a colorless, volatile liquid

18. Foreign Producers: UK	
19. Foreign Capacities: Pilot plant	
20. Military Uses: Used with either AN or AP in rocket propellant compositions, and with hexamethylene diisocyanate as a copolymer. Small amounts of ferric acetylacetonate are also used as the curing catalyst with a nitric ester plasticizer (e.g. NPN, or TNENP).	
21. Civil Uses: None	
22. Notes:	
23. References/MILSPECS:	

1. Substance or Composition:
Polynitrocubanes with more than four nitro groups

2. CAS Registry No.:
Not registrable

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):

5. Synonyms:

6. Chemical Composition:
$C_8(NO_2)_n$ where n=5,6,7, or 8

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
US Army, ARDEC, Picatinny NJ 07806-5000 Tel:(201) 724 5473; FAX: (201) 724-5713; DSN 880-5473; Contact: Dr. Sury Iyer.

14. Production Capacity:
Limited

15. Cost:
Not available

16.	**Shipping Pack & Label:** Hazard Class 1,1 explosives
17.	**Color & Form:** Not available
18.	**Foreign Producers:** None
19.	**Foreign Capacities:** None
20.	**Military Uses:** Powerful high explosives and solid propellant ingredients
21.	**Civil Uses:** None
22.	**Notes:** These three-dimensional, or cage, molecular structures represent theoretically important high explosive compounds with detonation pressures potentially up to 50 percent greater than that of HMX. Some may be potential high density (lower volume) missile propellant ingredients, or if hydrogen-free, reduced "signature" propellants. None are yet fully successful developments, and thus are more reflective of emerging technologies that bear continual watching. Because of the prospects they hold for breaking out of present limitations on explosives performance, there is a risk of rapid and wide dissemination of the technologies, if successful. The current consensus is that any polynitrocubane higher than the tetranitro compound should be controlled. Also of potential interest are the dinitramino salts and particularly the 1,2,4,7- and 1,3,5,7-tetraminocubanes. These substances are, however, all likely to be expensive to produce in quantity.
23.	**References/MILSPECS:**

1. Substance or Composition: Polynitroorthocarbonate **2. CAS Registry No.:** More info. needed **4. Acronym(s) or Trade Designation(s):** TNEOC	**3. Molecular Structure:** See Composition
5. Synonyms: Trinitroethylorthocarbonate	
6. Chemical Composition: $[C(NO_2)_3 CH_2)]_4 C$	
7. Control Status: Controlled by ML-8 Note 2	
8. Quality: Not specified	
9. Precursors: Classified	
10. Precursor Quality: Not specified	
11. Production Process: Classified	
12. Production Equipment: Not specified	
13. U.S. Producers: Unknown	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label: Not determined	
17. Color & Form: Unknown	
18. Foreign Producers: Italy?	
19. Foreign Capacities: Unknown	

20.	**Military Uses:** None (See notes)
21.	**Civil Uses:** Unknown
22.	**Notes:** The U.S. Navy, NSWC, White Oak, MD (which submitted this entry) has commented that the materials appear not to be militarily useful. The structure and preparation of these so-called Gilligan polymers were classified by the US Navy, although they can probably now be declassified.
23.	**References/MILSPECS:**

1. Substance or Composition: Potassium dinitramide	**3. Molecular Structure:** $K^+ N(NO_2)_2^-$
2. CAS Registry No.: 140456-79-7	
4. Acronym(s) or Trade Designation(s): KDN	

5. Synonyms:

6. Chemical Composition:
KN_3O_4

7. Control Status:
Not controlled, but of interest

8. Quality:
Not specified

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Thiokol Corp.,
Science & Engineering,
P.O. Box 707, MS 244,
Brigham City UT 84302.
Tel: (801) 863-6156; FAX: (801) 863-2271.
Dr. Robert B. Wardle.

14. Production Capacity: Limited	**15. Cost:** Not available

16. Shipping Pack & Label:
Not determined

17. Color & Form:
White crystals

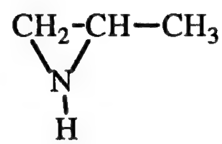
18. Foreign Producers:
None known.

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Potential oxidizer for use as a stabilizer with ammonium nitrate or with ADN for strategic missile propulsion systems.
21.	**Civil Uses:** Potential use for space-shuttle propulsion systems.
22.	**Notes:** KDN is used in a co-crystallized form with ammonium nitrate, which is under consideration as an oxidizer for space-launch propulsion systems. Although not currently listed in the MCTL.
23.	**References/MILSPECS:**

1. Substance or Composition:
Propyleneimine

2. CAS Registry No.:
75-55-8

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):

5. Synonyms:
2-methylaziridine; 1, 2–propyleneimine

6. Chemical Composition:
C_3H_7N

7. Control Status:
Controlled by ML-8 Note 5; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:

10. Precursor Quality:

11. Production Process:

12. Production Equipment:

13. U.S. Producers:
Arsynco, Carlstad NJ, subsidiary: Aceto Corp., 126-02 Northern Blvd., Flushing, NY.

14. Production Capacity:
Unknown

15. Cost:
Not available

16. Shipping Pack & Label:
Not determined

17. Color & Form:
Not determined

18. Foreign Producers:
U.K.? France?

19. Foreign Capacities:
Unknown

20. Military Uses:
Precursor for the manufacture of MAPO

21.	**Civil Uses:** Unknown
22.	**Notes:** The USML entry requires editing.
23.	**References/MILSPECS:**

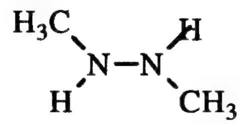
1. Substance or Composition: Salts of tetraethylenepentamine acrylonitrile glycidol **2. CAS Registry No.:** Not registrable **4. Acronym(s) or Trade Designation(s):**	**3. Molecular Structure:** Not applicable
5. Synonyms: Salts of cyanoethylated polyamine adducted with glycidol	
6. Chemical Composition:	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: 3M Company, Specialty Chemicals Div., 3M Center, 236-2A-01, St. Paul MN 55144-1000. Tel: 612 458-1392; FAX: (612) 458-1383. Dr. Anthony P. Manzara	
14. Production Capacity: Unknown	**15. Cost:** Not available
16. Shipping Pack & Label:	
17. Color & Form:	
18. Foreign Producers: Unknown	
19. Foreign Capacities: Unknown	

20.	**Military Uses:** Solid propellant additives
21.	**Civil Uses:** None
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition:
Symmetrical dimethyl hydrazine

2. CAS Registry No.:
540-73-8

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
SDMH

5. Synonyms:
1, 2 dimethyl hydrazine

6. Chemical Composition:
$(CH_3)_2(NH)_2$; or $C_2H_8N_2$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12.

8. Quality:
Not specified

9. Precursors:
Hydrazine, UDMH; so production capacity below

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Olin Corp., Cheshire CT. Tel: (203) 356-4071. Dr. Karl Seefried, VP Technology.

14. Production Capacity:
Not produce explicitly, except as a by-product within UDMH

15. Cost:
Not applicable

16. Shipping Pack & Label:
UN Hazard Class 6.1, toxic substance; subsidiary risk Class 3, flammable liquid; and Class 8, corrosive substance.

17. Color & Form:
Liquid, colorless; hygroscopic

18. Foreign Producers:
Unknown

19. Foreign Capacities: Unknown	
20. Military Uses: Liquid propllant fuel	
21. Civil Uses: None	
22. Notes:	
23. References/MILSPECS:	

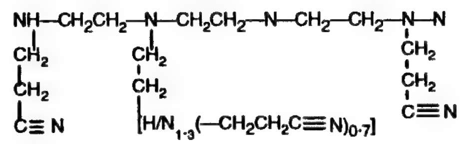
1. Substance or Composition: Tetraacetyldibenzylhexa-azaisowurtzitane **2. CAS Registry No.:** Not registered **4. Acronym(s) or Trade Designation(s):** TAIW	**3. Molecular Structure:** Classified
5. Synonyms:	
6. Chemical Composition: $C_{28}H_{32}O_4N_4$	
7. Control Status: Controlled by ML-8 Note 5; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Classified	
10. Precursor Quality: Not specified	
11. Production Process: Classified	
12. Production Equipment: Classified	
13. U.S. Producers: Thiokol Corporation	
14. Production Capacity: Pilot plant quantities	**15. Cost:** Not available
16. Shipping Pack & Label: Not established	
17. Color & Form: White powder	
18. Foreign Producers: Unknown	
19. Foreign Capacities: Unknown	
20. Military Uses: Manufacture of CL-20	

21.	**Civil Uses:** None
22.	**Notes:** TAIW is a precursor for the preparation of CL-20 . Its structure, preparation, and availability are classified.
23.	**References/MILSPECS:**

1. Substance or Composition:
Tetraethylenepentamine-acrylonitrile

2. CAS Registry No.:
68412-45-3

3. Molecular Structure:



= TEPAN, has many isomers and homologs

4. Acronym(s) or Trade Designation(s):
TEPAN;
HX-879

5. Synonyms:
"Reaction production of tetlenepentamine and acrylonitrile"
[Assumed erroneous for product of ethylenepentamine, etc.];
cyanoethylated polyamine;
TEPAN has many isomers & homologs.

6. Chemical Composition:
$C_{17}H_{30}N_8$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9. Precursors:
Tetraethylene pentamine; acrylonitrile

10. Precursor Quality:
Not specified

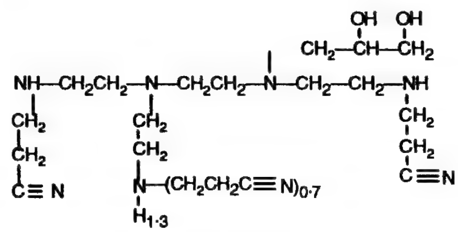
11. Production Process:
Reaction of tetraethylene pentamine with acrylonitrile. It needs to be refrigerated.

12. Production Equipment:

13. U.S. Producers:
3M Company, Specialty Chemicals Div.,
3M Center, 236-2A-01,
St. Paul MN 55144-1000.
Tel: 612 458-1392;
FAX: (612) 458-1383.
Dr. Anthony P. Manzara

Boulder Scientific Co.,
PO Box 548,
Mead CO 80542.
Tel: (303) 442-1199;
Fax:(303) 535-4584.
Contact: Dr. John Birmingham.

14. Production Capacity: Tons/year(3M) 10,000+ lb./yr. (Boulder)	**15. Cost:** $5.00/lb.
16. Shipping Pack & Label: Packaged in 1 and 40 lb units. Must be held in refrigerated storage at about -18°C(0°F). Shelf life is one year under proper storage.	
17. Color & Form: Amber liquid.	
18. Foreign Producers: It has been licensed for shipment to SNPE, France, and SNIA-BPD, Italy, who are purchasing experimental quantities from the Atlantic Research Co. There has been a request from 3M to OMC to make TEPAN in Belgium at a level of 6 tons/year.	
19. Foreign Capacities: Unknown	
20. Military Uses: Bonding agent used in AP-based missile propellants in quantities ranging from 0.05–0.5%. It reduces the viscosity (extends pot life) and improves the mechanical properties of the cured propellant. Used in all US /NATO versions of MLRS.	
21. Civil Uses: None except space -launch systems?	
22. Notes: A paper presented in Karlsruhe, Germany in 1986 on Tepan perchlorate suggests that Tepan has been prepared by China.	
23. References/MILSPECS:	

1. Substance or Composition: Tetraethylenepentamine acrylonitrile glycidol	**3. Molecular Structure:** 
2. CAS Registry No.: 68412-46-4	
4. Acronym(s) or Trade Designation(s): TEPANOL; Dynamar™ Bonding agent/Processing aid HX-878	

5. Synonyms:
Cyanoethylated polyamine adducted with glycidol;
Reaction product of tetraethylenepentamine, acrylonitrile, and glycidol

6. Chemical Composition:
See molecular structure above

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9. Precursors:
Tetraethylene pentamine; acrylonitrile; glycidol

10. Precursor Quality:
Not specified

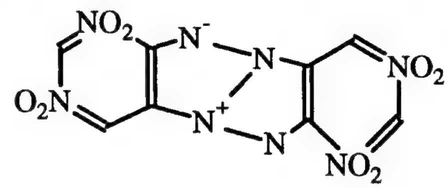
11. Production Process:
Reaction of tetraethylene pentamine with acrylonitrile and glycidol. It is mildly unstable and needs to be refrigerated.

12. Production Equipment:
Proprietary

13. U.S. Producers:
3M Company, Specialty Chemicals Div.,
3M Center, 236-2A-01,
St. Paul MN 55144-1000.
Tel: 612 458-1392;
FAX: (612) 458-1383.
Dr. Anthony P. Manzara

14. Production Capacity: Tons/year?	**15. Cost:** Not available

16.	**Shipping Pack & Label:** Packaged in 1 or 40 lb refrigerated units; storage at -18°C (0°F) is required and protection from moisture. Shelf life is then one year.
17.	**Color & Form:** Amber liquid
18.	**Foreign Producers:** Has been shipped to Israel, Germany, Italy and Japan. China probably has made it.
19.	**Foreign Capacities:**
20.	**Military Uses:** A bonding agent and processing aid for use with AP-based propellants. When added to the formulation at a concentration of 0.5% by weight, HX-878 helps to reduce the mix viscosity and improve the mechanical properties of the cure.
21.	**Civil Uses:** Not determined
22.	**Notes:** A paper presented in Karlsruhe, Germany in 1986 on Tepan perchlorate suggests that Tepanol has been prepared by China.
23.	**References/MILSPECS:** MIL-T-82824

1. Substance or Composition: Tetranitrobenzotriazolobenzotriazole	**3. Molecular Structure:** 
2. CAS Registry No.: 25243-36-1	
4. Acronym(s) or Trade Designation(s): TACOT	

5. Synonyms:
1,3,7,9-tetranitro-6H-benzotriazolo-[2,1-a]-benzotriazol-5-ium, inner salt; Tetranitrodibenzo-1,3a,4,6a-tetrazapentalene

6. Chemical Composition:
$C_{12}H_4N_8O_8$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
None specified

9. Precursors:
None specified

10. Precursor Quality:
N/A

11. Production Process:
Not known (See notes)

12. Production Equipment:

13. U.S. Producers:
An original product of the Dupont Company, but not believed to have been produced in quantity for 25 years or more.

14. Production Capacity: Unknown	**15. Cost:** >$200 per lb.

16. Shipping Pack & Label:
No UN Hazard Class assigned; nominally a Class 1.1 explosive.

17. Color & Form:
Orange to red crystals

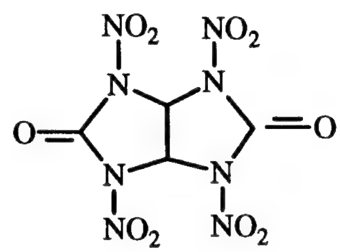
18. Foreign Producers:
None known; a German patent was granted in 1964 (Ref. 1).

19.	**Foreign Capacities:** None known
20.	**Military Uses:** A heat-resistant high explosive likely to be used in less sensitive munitions, and strategic defense and space applications in spite of its very high cost. It has been used in fuze priming compositions, and in detonating sheet explosives, also sometimes referred to as flexible explosives.
21.	**Civil Uses:** None
22.	**Notes:** Stocks of the substance are believed to exist only at ARDEC, Picatinny Arsenal, and possibly in DOE laboratories.
23.	**References/MILSPECS:** 1. R. A. Carboni, Ger. Patent 11649001964 [not seen, Chem. Abstr. 61,1701 (1964) indicates the patent describes preparation, properties, and uses.]

1. Substance or Composition:
Tetranitroglycoluril

2. CAS Registry No.:
55510-03-7

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
TNGU, or Sorguyl

5. Synonyms:
1,3,4,6-Tetranitroglycoluril
Tetranitroacetylenediurein;
2,4,6,8-tetranitro-2,4,6,8-tetraaza(dione);
Bicyclo(3,3,0)octone-3,7-dione;
Glycoluril-tetranitramine

6. Chemical Composition:
$CH_2N_8O_{10}$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
Not specified

9. Precursors:
Glycoluril or DNGU

10. Precursor Quality:
Not specified

11. Production Process:
Nitration of glycoluril or DNGU with nitric acid and phosphorus pentoxide

12. Production Equipment:

13. U.S. Producers:
None; has been made in limited quantities at LANL, NM

14. Production Capacity:
Limited

15. Cost:
Not available

16. Shipping Pack & Label:
No UN Hazard Class assigned; but nominally a Class 1.1 explosive

17.	**Color & Form:** White crystals
18.	**Foreign Producers:** SNPE, Sorgues, France; China?
19.	**Foreign Capacities:** Limited
20.	**Military Uses:** High explosive warhead fill.
21.	**Civil Uses:** None
22.	**Notes:** Tetranitroglycoluril, also known as a nitroacetylenediurein was originally prepared in 1888 and re-investigated during World War II and the Korean War period by the U.S. Army Ordnance Corps. During the latter period it was determined that several isomers of the substances can be formed and that their performance potential was equal to or better than PETN, RDX, and HMX. However, the tetra-derivative in particular is sensitive to impact, and both substances showed hydrolytic instability. Military interest waned. SNPE, Sorgues, France, renewed interest in TNGU beginning in the late 1970s under the names Sorguyl with a density and detonation velocity of 2.01 g/ml and 9150 m/s respectively. Stability was reported to be achieved through control of the isomer content during manufacture. The sensitivity of Sorguyl has, however, continued to be a problem. To date it has been made only in limited quantities in the U.S. in DOE laboratories, but continues to have potential for use in less-vulnerable compositions under development. FSU interest in the substance has not been determined. China (CH), however, synthesized DNGU, and related substances such as tetranitroethane, TNAE, possibly 15 or 25 years ago.
23.	**References/MILSPECS:**

1. Substance or Composition: Titanium	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: 7440-32-6	
4. Acronym(s) or Trade Designation(s): Cerac # T-1191	

5. Synonyms:

6. Chemical Composition:
Ti

7. Control Status:
Not controlled, but fine powder is a material of interest.

8. Quality:
<10 micrometer powder; or 1-3 micrometer powder; 99% purity

9. Precursors:
None specified; but see Process below

10. Precursor Quality:
Not specified

11. Production Process:
Reduction of $TiCl_4$ with Mg or Na in a He or Ar atmosphere

12. Production Equipment:
Proprietary

13. U.S. Producers:
Cerac Inc.,
PO Box 1178,
Milwaukee, WI 53201.
Tel: (414) 289-9800;
FAX (414) 289-9805.

Possibly also Ventron. Beverly, MA

14. Production Capacity: Dependent on demand	**15. Cost:** $727-848/kg

16. Shipping Pack & Label:
UN Class 4.1 (Shipped under not <25% water)

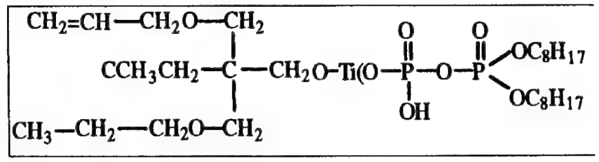
17. Color & Form:
Dark gray, lustrous metallic powder

18.	**Foreign Producers:** No known, foreign producers of this quality; but lower grade material is widely available in FSU, other NATO countries, and elsewhere.
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Pyrotechnic ordnance, including high explosive/incendiary cluster bombs; propellant igniter compositions with perchlorates(qv)
21.	**Civil Uses:** None
22.	**Notes:** Fine titanium powder (<10 micrometer) is used uniquely in the ordnance industry and is manufactured only by the Cerac (Milwaukee, WI) and perhaps Ventron (Beverly, MA) companies in the USA, whereas within the U.S. alone there are numerous companies able to produce >10 micrometer material. Titanium ores are among the most abundant in the world, although most are very low grade.
23.	**References/MILSPECS:** MIL-T-13405D

1. Substance or Composition:
Titanium IV [(2-propenolato-1)methyl, n-propanolatomethyl] butanolato-1, tris(dioctyl)pyrophosphato

2. CAS Registry No.:
None

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
KR3538

5. Synonyms:

6. Chemical Composition:
A hindered, non-alkoxy hydrolyzable titanate coupling agent

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12 (See notes.)

8. Quality:
Not specified

9. Precursors:
Alkyl-propyl trimethylol propane

10. Precursor Quality:
Not specified

11. Production Process:

12. Production Equipment:

13. U.S. Producers:
Kenrich Petrochemicals, Inc. 140 E. 22nd St., Bayonne NJ 07002-0032.
Tel: 201-823-9000; Fax 201-823-0691.
POC: Mr. Sal. Monte, President.

14. Production Capacity:
Unknown

15. Cost:
$25.00/lb

16. Shipping Pack & Label:
Not determined

17. Color & Form:
Not determined

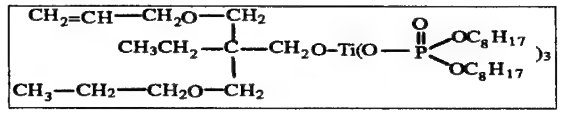
18. Foreign Producers:
None

19.	**Foreign Capacities:** None
20.	**Military Uses:** Experimental missile propellant ingredient
21.	**Civil Uses:** Not determined
22.	**Notes:** The entry in the USML needs editing.
23.	**References/MILSPECS:**

1. Substance or Composition:
Titanium IV[(2-propenolato-1) methyl, N-propanolatomethyl] butanolato-1, tris(dioctyl)phosphato

2. CAS Registry No.:
None

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
KR3512

5. Synonyms:
A hindered, non-alkoxy hydrolyzable titanate coupling agent

6. Chemical Composition:

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12. (See notes.)

8. Quality:
Not specified

9. Precursors:
Alkyl-propyl trimethylol propane

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Kenrich Petrochemicals, Inc.
140 E. 22nd St.,
Bayonne NJ 07002-0032.
Tel: 201-823-9000;
Fax 201-823-0691.
POC: Mr. Sal. Monte, President.

14. Production Capacity:
Unknown

15. Cost:
$25 per lb

16. Shipping Pack & Label:
Not determined

17. Color & Form:
Not determined

18.	**Foreign Producers:** None
19.	**Foreign Capacities:** None
20.	**Military Uses:** Experimental missile propellant additive
21.	**Civil Uses:** None
22.	**Notes:** The entry in the USML needs editing.
23.	**References/MILSPECS:**

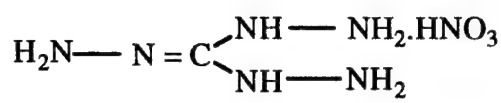
1. Substance or Composition: Titanium subhydride	**3. Molecular Structure:** Not available
2. CAS Registry No.: 7704-98-5 (relates to TiH_2)	
4. Acronym(s) or Trade Designation(s):	
5. Synonyms:	
6. Chemical Composition: TiH of stoichiometry $TiH_{0.65-1.68}$	
7. Control Status: Controlled by ML-8 Note 1a; USML CAT V §121.12	
8. Quality: Defined by listed stoichiometry	
9. Precursors: Titanium metal or TiO_2	
10. Precursor Quality: Not specified	
11. Production Process: Reaction of Ti with hydrogen; or by reduction of TiO_2 with Ca in the presence of hydrogen	
12. Production Equipment: Proprietary	
13. U.S. Producers: Mound Facility, Miamisburg, OH, now managed by EG&C Corp. for the Department of Energy and for Sandia National Lab.	
14. Production Capacity: Probably only a few kilograms per year	**15. Cost:** Not available
16. Shipping Pack & Label: UN Hazard Class 4.1, flammable solid (probably relates to TiH_2)	
17. Color & Form: Dark gray or black metallic powder	
18. Foreign Producers: FSU	
19. Foreign Capacities: Unknown	

20.	**Military Uses:** Ignitors and solid rockets propellants for defense systems
21.	**Civil Uses:** Refractory hard metals synthesis using low quality TiH_2
22.	**Notes:** A sponge form of the parent metal is normally required to produce the hydrides. Limited capability to prepare the substances exists outside the U.S. in NATO (Germany), and in the former Warsaw Pact countries, but only laboratory-scale investigations may have been conducted. No production capability outside the U.S. is known. As far as determined, titanium hydrides of controlled stoichiometry as listed are manufactured only in the U.S. The lower limit of the listed range, $TiH_{0.65}$, represents older technology; $TiH_{1.68}$, the newer technology. Other listed metal hydrides include beryllium hydride, for application in missiles and space vehicles, and encapsulated lithium and lithium aluminum hydrides.
23.	**References/MILSPECS:**

1. Substance or Composition:
Triaminoguanidine nitrate

2. CAS Registry No.:
4000-16-2

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
TAGN

5. Synonyms:

6. Chemical Composition:
$CH_9N_7O_3$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12

8. Quality:
None specified

9. Precursors:
Guanidine nitrate

10. Precursor Quality:
None specified

11. Production Process:
Reaction of guanidine dinitrate and hydrazine hydrate; or by aqueous fusion of hydrazine and Ca cyanamide

12. Production Equipment:
Not specified

13. U.S. Producers:
Not determined

14. Production Capacity:
Unknown

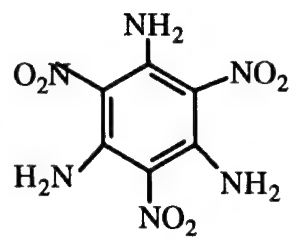
15. Cost:
Not available

16. Shipping Pack & Label:
No UN Hazard Class assigned (explosion temperature is 260°C.

17. Color & Form:
Colorless crystals

18. Foreign Producers:
Germany;
South Africa;
Harina Plant, Daicel Chemical Industries, Japan;
Australia (Small facility only)

19. Foreign Capacities: Unknown	
20. Military Uses: An igniter or burning-rate modifier for gun and missile propellants; an oxidizer for cool-burning, rapid-fire gun propellants.	
21. Civil Uses: None	
22. Notes: TAGN is manufactured in the U.S. and in Germany only in limited quantities. A source of guanidine nitrate is also required as a precursor for TAGN. A high-quality product is essential for reliable propellant performance, and no country's product yet matches the quality of the U.S. material. Japan has at least an experimental capability to make TAGN, and Australia may soon develop its own capability. Outside NATO, Sweden may have a capability to manufacture TAGN; the following countries have significant requirements or capability: • Brazil purchases TAGN directly from Germany or Italy (see NQ), or manufactures the substance from GN purchased from Germany. The quality is not up to U.S./NATO standards. • The Republic of South Africa manufactures TAGN from the indigenous, high quality GN. However, the quality is not as high as that achieved and considered necessary in the U.S. • The FSU's capabilities and interests in regard to TAGN are not known, but development of an NQ capability may have given them an incipient capability to make TAGN. Considerable expertise is necessary to obtain the level of yields and quality considered necessary for reliable performance and economic viability in the U.S.. It may be presumed that FSU engineers would be faced with significant process development problems in meeting these objectives.	
23. References/MILSPECS:	

1. Substance or Composition: Triaminotrinitrobenzene	**3. Molecular Structure:** 
2. CAS Registry No.: 3058-38-6	
4. Acronym(s) or Trade Designation(s): TATB	
5. Synonyms: 2,4,6-trinitro-1,3,5-benzenetriamine; 1,3,5-triamino-2,4,6-trinitrobenzene	
6. Chemical Composition: $C_6H_6N_6O_6$	
7. Control Status: Controlled by ML-8 Note 1a; USML CAT V §121.12; NDUL 6.4	
8. Quality: Not specified	
9. Precursors: 1,3,5-trichlorobenzene (TCTNB)	
10. Precursor Quality: Not specified	
11. Production Process: Nitration of TCTNB with mixed nitric/sulfuric acids; LLNL is reported to have patented a process for making TATB from TNT and hydrazine	
12. Production Equipment: 100 gal. or larger stainless steel reactors	
13. U.S. Producers: Aerojet-General Corporation; Hercules Corp., McGregor, TX; DOD/DOE in-house laboratories (in small quantities).	
14. Production Capacity: Unknown	**15. Cost:** >$30 per pound
16. Shipping Pack & Label: Not assigned a UN Hazard Class; nominally Class 1.1.	

17. Color & Form:
Light (bright) yellow crystals

18. Foreign Producers:
A pilot plant existed at Royal Ordnance, Waltham Abbey, UK., and may have been moved to a new site. FSU, China, Egypt, France may all have some capability (See Notes).

19. Foreign Capacities:
Unknown

20. Military Uses:
Chemical explosive in nuclear warheads; potential conventional warhead fill where performance can be sacrificed for safety.

21. Civil Uses:
None; possible but expensive oil well penetrator fill.

22. Notes:
TATB is manufactured in the U.S. by the Aerojet-General Corporation, by Hercules Corp., McGregor, TX, and in small quantities in DOD/DOE in-house laboratories. The Aerojet product is considered to be the best available. A pilot plant for its manufacture also exists at Royal Ordnance, Waltham Abbey, UK. The cost of the substance limits its application, but in certain circumstances where nuclear weapons safety, or extreme invulnerability to impact, are requirements, it is used in warheads. The U.S. and the UK were in 1988 the only countries known to be producers, albeit in limited quantities. However, among NATO allies France may also be a producer, as it is an exploiter of TATB applications (Ref. 1).

A paper referenced in the FSU to 1980 (Ref. 2), describing the desensitization of high explosives by TATB, suggests that at least a small manufacturing capability existed in the FSU at that time. It has been claimed that CH prepared TATB and experimented with plastic bonded formulations prior to the U.S.. The priority may be questioned, but the efforts were presumably for nuclear weapons applications; it is not known whether a significant production capability exists. Moreover, a paper presented in Karlsruhe, Germany, in 1986 suggests that studies have been conducted in Egypt to produce TATB by the amination of pentanitroaniline. Egypt is continuing to develop TATB formulations and may by now have developed its own plant, drawing on the development of such a process.

23. References/MILSPECS:

1. Nicollet, M., R. Belmas, J. Plotard, B. Udiment, and M. Leroy, *Propellants, Explos., Pyrotech.* 1993, *18*, 128.
2. Kofman, T. P., M. S. Pevsner, L. N. Zhukova, T. A. Kravchenko, and G. M. Frolova, *Zh. Org. Khim.* 1980, *16*, 2.

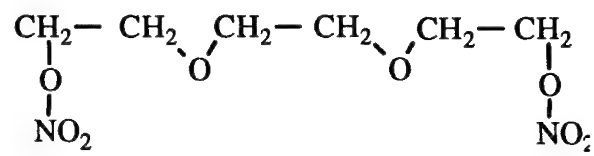
1. Substance or Composition: Triethylborane	**3. Molecular Structure:** See composition
2. CAS Registry No.: 97-94-9	
4. Acronym(s) or Trade Designation(s): TEB	
5. Synonyms: Triethylborine; Boron triethyl Carborane	
6. Chemical Composition: $(C_2H_5)_3B$	
7. Control Status: Controlled by ML-8, Note 1a.	
8. Quality: Not specified	
9. Precursors: TEA and a boron halide; or diborane and ethylene; or n-butyl ether solution of BF_3 and ethyl Mg.	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: Callery Chemical Co., Route 309, Mars-Evans City Road, Callery, PA 16024. Contact: Ms. Beverly Jones. Tel: (412) 967 4248 FAX: (412) 967-4270	
14. Production Capacity: Limited	**15. Cost:** Not available
16. Shipping Pack & Label: UN Hazard Class 4.2;; also 6.1, toxic substance	
17. Color & Form: Colorless pyrophoric liquid	

18.	**Foreign Producers:** Unknown
19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Pyrophoric incendiary agent; missile fuel
21.	**Civil Uses:** None
22.	**Notes:** It is proposed that the existing boron hydride entries be replaced with entries for specific boranes. Carboranes, in general, are not made regularly; other related compounds include Cesium II $B_{12}H_{12}$, which is used for gas generators and pyridine borane which has only civil applications. A further potential source of the compounds is: Boulder Scientific Co., PO Box 548, Mead CO 80542. Tel: (303) 442-1199; Fax:(303) 535-4584. Contact: Dr. John Birmingham.
23.	**References/MILSPECS:**

1. Substance or Composition:
Triethylene glycol dinitrate

2. CAS Registry No.:
111-22-8

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
TEGDN; TEGN

5. Synonyms:
Triglycol dinitrate

6. Chemical Composition:
$C_6H_{12}N_2O_8$

7. Control Status:
Controlled by MTCR; specifically not controlled by ML-8

8. Quality:
Not specified

9. Precursors:
Triethylenegylcol

10. Precursor Quality:

11. Production Process:
Nitration of triethyleneglycol with mixed nitric/sulfuric acids.

12. Production Equipment:

13. U.S. Producers:
Radford Army Ammunition Plant, Radford VA

14. Production Capacity:
Significant

15. Cost:
Not available

16. Shipping Pack & Label:
Hazard class 6.1, toxic substance; Class 1.1 explosive, depending on confinement and dilution.

17. Color & Form:
Light yellow oily liquid.

18. Foreign Producers:
Most countries that have continuous, Bazzi type nitroglycerine plants.

19. Foreign Capacities:

20.	**Military Uses:** Nitrocellulose plasticizer for double base propellants; ingredient of flexible sheet high explosives.
21.	**Civil Uses:** Ingredient in liquid rock blasting explosives; oil well stimulation
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition: Trimethylolethane trinitrate [see also MTN]	**3. Molecular Structure:** See composition
2. CAS Registry No.:	
4. Acronym(s) or Trade Designation(s): TMETN	

5. Synonyms:
Trimethylolethane trinitrate

6. Chemical Composition:
$CH_3C(CH_2ONO_2)_3$

7. Control Status:
Controlled by MTCR; but specifically not controlled by ML-8

8. Quality:
Not specified

9. Precursors:
See box 11 below

10. Precursor Quality:
Not specified

11. Production Process:
Nitration of methyl trimethylol methane with nitric/sulfuric acids.

12. Production Equipment:
Could be made in almost any continuous nitroglycerin plant

13. U.S. Producers:
Any producer of nitroglycerin

14. Production Capacity: Significant	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 1.1

17. Color & Form:
Viscous, colorless, odorless oil

18. Foreign Producers:
Almost all developed countries possessing nitroglycerin plant

19. Foreign Capacities:
Very significant

20. Military Uses:
Flash and erosion reducing agent in gun propellants. Mixed with 8% metriol triacete (not controlled) it gelatinizes NC for use in gun, missile, and rocket propellants, e.g. in Chaparral, Hellfire, Trident systems.

21. Civil Uses:
Used in commercial high explosives and ammunition

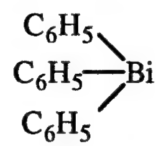
22. Notes:
The substance is almost as sensitive as nitroglycerin and does not have good thermal stability. See notes for Ethane-1,1,1-tris(hydroxymethyl) trinitrate.

23. References/MILSPECS:

1. Substance or Composition:
Triphenyl bismuth

2. CAS Registry No.:
603-33-8

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
TPB

5. Synonyms:

6. Chemical Composition:
$C_{18}H_{15}Bi$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9. Precursors:
Bismuth and petroleum products

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Boulder Scientific Co.,
PO Box 548,
Mead CO 80542.
Tel: (303) 442-1199;
Fax:(303) 535-4584.
Contact: Dr. John Birmingham.

14. Production Capacity:
100 lb./yr.; capable of 1000's lb./yr. subject to demand

15. Cost:
$80 per lb.

16. Shipping Pack & Label:
No UN Hazard Class; shipped in fiber drums; 100 lb. per drum.

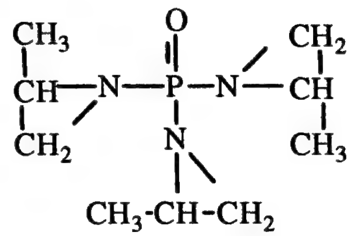
17. Color & Form:
White-colorless, fine powder

18.	**Foreign Producers:** None
19.	**Foreign Capacities:**
20.	**Military Uses:** Polymerization catalyst for missile propellant binders
21.	**Civil Uses:**
22.	**Notes:** Produced to meet about twenty different MILSPECs, adapted to each missile system.
23.	**References/MILSPECS:** MIL-T-70681 (see notes)

1. Substance or Composition:
Tris-1-(2-methyl)aziridinyl phosphine oxide

2. CAS Registry No.:
57-39-6

3. Molecular Structure:



4. Acronym(s) or Trade Designation(s):
MAPO

5. Synonyms:
Methylaziridine phosphine oxide

6. Chemical Composition:
$C_9H_{18}N_3OP$

7. Control Status:
Controlled by ML-8 Note 2; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9. Precursors:
Propyleneimine

10. Precursor Quality:
Not specified

11. Production Process:
Proprietary

12. Production Equipment:
Proprietary

13. U.S. Producers:
Dixey Chemical Co. produces basic material which is refined by:
Ensign Bickford Industries Inc.
660 Hopmeadow St.,
P.O. Box 427, Simsbury CT 06070-0427
Tel: (203) 843-2225
FAX:(203) 843-2621
Contact: Mr. Pete McGuinness

Arsynco subsidiary: Aceto Corp.,(A distributor only?)
126-02 Northern Blvd.,
Flushing NY

14. Production Capacity: 10,000 lb total	**15. Cost:** Not available

16. Shipping Pack & Label:
Not determined

17. Color & Form:
Not determined

18. Foreign Producers:
U.K.? France ?

19. Foreign Capacities:
Unknown

20. Military Uses:
Curing agent for CTPB propellants; and in Tomahawk missiles in particular.

21. Civil Uses:
Used in space shuttle

22. Notes:
MAPO is used in association with CTPB binder as a curing agent for solid propellant liners, but by itself the substance is hydrolytically unstable, causing the composition to fall apart. Therefore, it has not been used for some years by major propulsion companies such as Rocketdyne, Thiokol, Hercules, and Aerojet. It was used in the Minuteman, and it is still used in the space-shuttle liner, and experimentally in new gun propellants. In the shuttle liner an epoxy is also used in the composition to impart stability.

The substance has been used by defense contractors only; there is no known commercial market. There are potential British and French sources also for MAPO or related substances.

Proscribed country availability is not known, but is probably nonexistent. The product is reported to have been sold only to "friendly countries", including those in Europe and Japan. Requests for 8–10 lb quantities have been received from Romania, and CH, but were denied.

The related nonmethylated product tris(1-aziridinyl) phosphine oxide has been used as a flame retardant for textiles, but is banned in most if not all NATO countries because of its toxicity. It has not been determined whether residual capacity for this substance exists, might be a source for MAPO, and is available to proscribed countries.

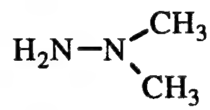
23. References/MILSPECS:
MIL-M-23945

1. Substance or Composition: Tris-1-(2-methyl)aziridinyl phosphine oxide derivatives	**3. Molecular Structure:**
2. CAS Registry No.: Not registrable	Not applicable (see MAPO)
4. Acronym(s) or Trade Designation(s): MAPO derivatives	
5. Synonyms:	
6. Chemical Composition: Not applicable (see MAPO)	
7. Control Status: Controlled by ML-8 Note 2; USML CAT V §121.12	
8. Quality: Not specified	
9. Precursors: Not specified	
10. Precursor Quality: Not specified	
11. Production Process: Proprietary	
12. Production Equipment: Proprietary	
13. U.S. Producers: 3M Company, Specialty Chemicals Div., 3M Center, 236-2A-01, St. Paul MN 55144-1000. Tel: 612 458-1392; FAX: (612) 458-1383. Dr. Anthony P. Manzara <u>Or</u>: Arsynco subsidiary: Aceto Corp., 126-02 Northern Blvd., Flushing NY	
14. Production Capacity: Not determined	**15. Cost:** Not available
16. Shipping Pack & Label: Not determined	
17. Color & Form: Not determined	

18.	**Foreign Producers:** None
19.	**Foreign Capacities:** None
20.	**Military Uses:** Experimental curing agent for polymer-bonded missile propellants.
21.	**Civil Uses:** None
22.	**Notes:**
23.	**References/MILSPECS:**

1. Substance or Composition:
Unsymmetrical dimethyl hydrazine

3. Molecular Structure:



2. CAS Registry No.:
57-14-7

4. Acronym(s) or Trade Designation(s):
UDMH

5. Synonyms:
1,1-Dimethylhydrazine

6. Chemical Composition:
$C_2H_8N_2$; or $(CH_3)_2NNH_2$

7. Control Status:
Controlled by ML-8 Note 1a; USML CAT V §121.12; MTCR

8. Quality:
Not specified

9. Precursors:
Nitrosodimethylamine (no longer used in U.S.); or dimethylamine and chloramine or urea

10. Precursor Quality:

11. Production Process:
(a) Reduction of nitrosodimethylamine (old FMC method); or
(b) Reaction of dimethylamine and chloramine or urea; or
(c) Catalytic oxidation of dimethylamine and ammonia

12. Production Equipment:
Proprietary

13. U.S. Producers:
Olin Corp.,
Cheshire CT.
Tel: (203) 356-4071.
Dr. Karl Seefried, VP Technology.

14. Production Capacity:

15. Cost:

16. Shipping Pack & Label:
UN Hazard Class 6B, toxic substance; subsidiary risk Class 3, flammable liquid; and Class 8, corrosive substance. Shipped in drums and in double-walled, pressurized tank cars of up to 4-5000 gal. capacity. Ship up to 40,000 lb at a time to support launches.

Shipped overseas also in double-walled cylinders; but France ships to French Guinea using single-walled vessels under 10 bar(150 lb)pressure, not legal in the U.S.

17.	**Color & Form:** Colorless, hygroscopic liquid with an odor of ammonia
18.	**Foreign Producers:** France; (SNPE), Russia; China
19.	**Foreign Capacities:** Significant
20.	**Military Uses:** Fuel in liquid propellant rocket motors; space vehicle thrusters
21.	**Civil Uses:** Commercial launch vehicles; Herbicide?
22.	**Notes:** Method (a) is believed no longer used for production of UDMH in the U.S. because of the carcinogenicity of the nitroso compound.
23.	**References/MILSPECS:** MIL 25604-D

1. Substance or Composition: Zinc dust/powder	**3. Molecular Structure:** Not applicable
2. CAS Registry No.: 7440-66-6	
4. Acronym(s) or Trade Designation(s):	

5. Synonyms:

6. Chemical Composition:
Zn

7. Control Status:
Controlled by MTCR

8. Quality:
Particle sizes <500 micro-meters, whether spherical, atomized, spheroidal, flaked , or ground consisting of 97% by weight or more of Zn

9. Precursors:
Not specified

10. Precursor Quality:
Not specified

11. Production Process:
Reduction of Zn sulfide and carbonate ores

12. Production Equipment:
Proprietary

13. U.S. Producers:
Meadowbrook Corp.
30 Rockefeller Plaza
New York, NY 10020
Tel: (212) 582-0420

14. Production Capacity: Not available	**15. Cost:** Not available

16. Shipping Pack & Label:
UN Hazard Class 4.3; emits flammable gases in contact with water.

17. Color & Form:
White metallic powder, with a bluish luster.

18. Foreign Producers:
Widely available

19.	**Foreign Capacities:** Unknown
20.	**Military Uses:** Smoke generating compositions, or as smoke inhibitor
21.	**Civil Uses:** Electrochemical batteries; a solvent for other metals and a reducing agent in pyrometallurgical applications.
22.	**Notes:**
23.	**References/MILSPECS:** MIL-Z-365A (Dust)

1. Substance or Composition: Zirconium powder **2. CAS Registry No.:** 7440-67-7 **4. Acronym(s) or Trade Designation(s):**	**3. Molecular Structure:** Not available

5. Synonyms:

6. Chemical Composition:
Zr

7. Control Status:
a. Controlled by ML-8 Note 1a ; USML CAT V §121.12; MTCR
b. Controlled by MTCR

8. Quality:
a. Powders in particle sizes <60 micro-meters whether spherical, atomized, spheroidal, flaked, [sponge], or ground.(ML, USML)
b. Particle sizes <500 micrometers, whether spherical, atomized, spheroidal, flaked , or ground consisting of 97% by weight or more of Zr (MTCR)
Note: Zirconium sponge is not specifically covered by the controls but is an item of interest

9. Precursors:
Zirconium stock; zirconium sponge

10. Precursor Quality:
a. 99% or greater purity
b. 97% by weight or more of Zr

11. Production Process:
Reduction of Zr oxides with alkaline earth metals (e.g. Ca or Mg); or,
Vacuum reduction of Zr hydride

12. Production Equipment:
Proprietary

13. U.S. Producers:
Teledyne Wah Chang, 1600 Old Pacific Highway,
P.O. Box 460, Albany OR 97321-0136

14. Production Capacity:
Significant

15. Cost:
>$150/kg ($20-30/kg for sponge)

16. Shipping Pack & Label:
UN Hazard Class 4.2 (4.1 when wetted); often shipped with >25% water or water alcohol content, in wooden boxes in glass or non carbon polyethylene containers having net weight <10 lb.;
Zr sponge may be in plastic lined 30 gal. steel drums.

17.	**Color & Form:** Gray powder
18.	**Foreign Producers:** Degussa AG, Hanau, Germany FSU
19.	**Foreign Capacities:** Significant
20.	**Military Uses:** High explosive/incendiary (HEI) warheads and pyrotechnic munitions; ignition/initiation compositions and delays; thermal batteries.
21.	**Civil Uses:** Sheathing fuel rods for nuclear reactors; liners for reaction vessels; photoflash bulbs
22.	**Notes:** Adequate control of the listed fine powder is probably not achievable unless the sponge is also controlled. For example, Zr sponge is used directly as an incendiary ingredient in the BLU97 bomblet carried by the Joint Stand Off Weapon (JSOW).
23.	**References/MILSPECS:** MIL-Z-399D; MIL Z-47157(Zr powder) MIL-Z-50976(MU) (Zirconium sponge)

GLOSSARY

ADN	ammonium dinitramide
ADNBF	aminodinitrobenzofuroxan
AN	ammonium nitrate
ANMO	azidonitratomethyloxetane
AP	ammonium perchlorate
BAMO	bisazidomethyloxetane
BCMO	3,3 bis(chloromethyl)oxetane
BDNPA	bis(2,2-dinitropropyl)acetal
BDNPF	bis(2,2-dinitropropyl)formal
BHEGA	bishydroxyethyl glycolamide
BITA	butylene imine trimesamide
BNCP	cis-bis(5-nitrotetrazolato)pentaamminecobalt(III) perchlorate
BNMO	bis(nitratomethyl))oxetane
BOBBA 8	Bob's bonding agent no. 8; bis(2-methylaziridinyl) 2-(2-hydroxypropanoxy) propylamino phosphine oxide
BNO	butadienenitrileoxide
BTTN	butanetrioltrinitrate
Catocene	2,2-bis(ethylferrocenyl)propane
CL-14	5,7-diamino-4,6-dinitrobenzofurazane-1-oxide
CL-20	hexanitrohexaazaisowurtzitane
CTPB	carboxyl terminated polybutadiene
DADN	(1,5-diacetyloctahydro-3, 7-dinitro -1,3,5,7-tetrazocine)
DAF	diaminofurazan
DATB	diaminotrinitrobenzene
DEGDN	diethyleneglycoldinitrate
DFE	diferrocenylethane
DHG	oxalohydroxamic acid

DINGU, DNGU	dinitroglycoluril
DIPAM	diaminohexanitrobiphenyl
EDAD	ethylene diamine dinitrate
EDD	ethylene diamine dinitrate
EDDN	ethylene diamine dinitrate
EMCDB	elastomer-modified cast double bond propellant
ETC	electrothermal-chemical
FEFO	bis(2-fluoro-2,2-dinitro-ethyl)formal
GAP	glycidylazide polymer
GuN	guanidine nitrate
HAN	hydroxyl ammonium nitrate
HAP	hydroxyl ammonium perchlorate
HBIW	hexabenzylhexaazaisowurtzitane
HN	hydrazine nitrate
HNIW	hexanitrohexaazaisowurtzitane
HNS	hexanitrostilbene
HMX	high melting explosive; tetramethylene tetranitramine
HTPB	hydroxyl terminated polybutadiene
IPDI	isophoron diisocynate
IRFNA	inhibitted red fuming nitric acid
K-6	2,4,6-trinitro-2,4,6-triaza-cyclohexanone
K-55	2,4,6,8-tetranitro-2,4,6,8-tetraazabicyclo(3,3,0)-octanone-3
Ketobicyclo HMX	2,4,6,8-tetranitro-2,4,6,8-tetraazabicyclo(3,3,0)-octanone-3
Keto-RDX	2,4,6-trinitro-2,4,6-triaza-cyclohexanone
KDN	potassium dinitramide
MAPO	bis(2-methyl)aziridinyl phosphine oxide
Methyl BAPO	bis(2-methylaziridinyl)methylamino phosphine oxide
MMH	monomethyl hydrazine

MON	mixed nitrous oxide-nitrogen tetroxide
MTN (or TMETN)	metriol trinitrate
NC	nitrocellulose
NEPE	nitrate ester plasticized polyether
NG	nitroglycerin
NMMO	nitratomethyl-methyloxetane
NMNA	n-methyl-4-nitroaniline
NONA	nonanitroterphenyl
NQ	nitroguanidine
NSAN	non-stabilized ammonium nitrate
NTO	3-nitro-1,2,4-triazol-5-one
Octal	aluminum octadecanoate
Octol	HMX/TNT mixtures
OTN	See NTO
pNMA	p-Nitro-N-Methylaniline
PBAA	polybutadiene acrylic acid
PCDE	polycyanodifluoroaminoethyleneoxide
PGN, or poly-GLYN	polyglycidyl nitrate
PETN	pentaerythritol tetranitrate
Picrite	NGU or NQ (q.v.)
poly-NIMMO	poly-nitratomethyl-methyloxetane
PSAN	phase stabilized ammonium nitrate
PYX	picrylaminodinitropyridine
RDX	Research Department Explosive (a department at the Woolwich Arsenal, England, now no longer in existence); trimethylene trinitramine
SDMH	symmetrical dimethyl hydrazine

TACOT	tetranitrobenzotriazolobenzotriazole
TAGN	triaminoguanidine nitrate
TAIW	tetraacetyldibenzylhexaazaisowurtzitane
TAT	1,3,5,7-tetraacetyl-1,3,5,7-tetraazacyclooctane
TATB	triaminotrinitrobenzene
TEA	triethyl aluminum
TEAT	2-ethyl aziridine amide with isocyanuric backbone structure
TEB	triethylborane
TEGDN	triethyleneglycoldinitrate
Tetryl	trinitrophenylmethylnitramine
TMETN	See MTN
TMP	trimethylol propane
TNAD	tetranitrotetraazadecalin
TNAZ	trinitroazetidine
TNEOC	polynitroorthocarbonate; tri(nitroethyl)orthocarbonate
TNGU	tetranitroglycoluril
TNT	trinitrotoluene
TEPAN	tetraethylenepentamine-acrylonitrile
TEPANOL	tetraethylenepentamine acrylonitrile glycidol
TPB	triphenyl bismuth
TVOPA	1,2,3-tris[1,2 bis(difluoroamino) ethoxy] propane
UDMH	unsymmetricaldimethyl hydrazine

DEFINITIONS

Additives	Substances used in explosive formulations to improve their properties.
Brilliant munition	A "many-on-many" munition that operates autonomously to search for, detect, identify, acquire, and attack specific classes of targets. The sensor on each munition acquires and attacks one among the class of targets, so that in a battlefield situation two munitions may attack the same target, leaving others inviolate (see "Sentient" munition).
Bulk, or in bulk	A comparatively large quantity of a substance or commodity that is manufactured, shipped, and stored as such, but which is characteristically broken down into smaller lots before application or further processing.
CAS Numbers	The designated Chemical Abstract Service number.
Deflagration	A "surface" chemical reaction in which the reaction products travel away from reaction interface, characteristically at pressures of 1–100 bars and at velocities of 0.001–10 cm/sec (the velocity for a particular substance increasing with pressure).
Detonation	A chemically driven shock wave in which the reaction products propagate supersonically in the direction of the shock wave at 1–10 km/sec and at pressures of hundreds of kilobars.
Energetic materials	A collective term for military high explosives, propellants and pyrotechnics, which is synonymous with the term military explosives (the preferred NATO/New Forum usage). Although the term has been adopted by some also to cover commercial explosives, it is used in this handbook only to refer to military technology.
Fixed Ammunition	Ammunition rounds in which the cartridge with propellant and the loaded shell or "bullet" are all in one unit. With semifixed rounds the cartridge case is not permanently fixed to the projectile, so that zone charges within cases can be adjusted to obtain desired ranges, but each round is inserted into a weapon as a unit.

Impulse, specific	The "thrust" developed in burning unit weight of a propellant, corrected for standard operating and discharge pressures. Specific impulse may be measured, or estimated theoretically from the thermochemical properties of propellant formulations and their decomposition products.
Impulse, total	The integral of the "thrust" of a rocket motor over the burning time. Other factors being equal the same total impulse can result from a small "thrust" over a long burn time as from a high "thrust" over a short burn time.
IUPAC	International Union of Pure and Applied Chemistry; maintains a database of organic nomenclature.
Mass fraction	The ratio of the weight of the propellant to the weight of the loaded rocket. The larger the ratio the longer the range of the rocket.
Military explosives	The preferred NATO collective term for military high explosives, propellants (low explosives), and pyrotechnics.
Military high explosives	Solid, liquid or gaseous substances or mixtures of substances that, in their application as primary, booster, or main charges in warheads, demolition and other military applications, are required to detonate.
Military propellants	Solid, liquid or gaseous substances or mixtures of substances that are used for propelling projectiles and missiles, or to generate gases for powering auxiliary devices for embargoed military equipment and that, when ignited, burn or deflagrate to produce quantities of gas capable of performing work; but in their application these quantities are required not to undergo a deflagration to detonation transition.
Military pyrotechnics	Mixtures of solid or liquid fuels and oxidizers that, when ignited, undergo an energetic chemical reaction at a controlled rate intended to produce specific time delays, or quantities of heat, noise, smoke, visible light, or infrared radiation. Pyrophorics are a subclass of pyrotechnics, that contain no oxidizers but ignite spontaneously on contact with air.
Minimum smoke	A descriptive term used for propellants that produce the least amount of smoke under specified conditions. The term is difficult to quantify, but the Advisory Group for Aerospace Research and Development (AGARD) identifies these as class AA propellants.

Obscurant	A substance or radiation absorber that blocks the radiation emitted from a target, thereby preventing the continuous tracking or detection of the target.
Oxygen balance	A measure of the fuel:oxygen ratio in a substance; for example, the (positive) percentage of excess oxygen by weight in a composition, liberated by the complete oxidation of an explosive's substituents to CO_2, H_2O, SO_2, Al_2O_3, etc. If insufficient oxygen is available to effect complete oxidation, the substance is said to be oxygen deficient (or have a negative oxygen balance). Ammonium perchlorate has a value of + 34 percent relative to CO_2; Aluminum has a value – 89.0 percent .
Precursors	Specialty chemicals used in the manufacture of military explosives.
Primary smoke	The solid particulates from the combustion of a fuel, pyrotechnic, or propellant. Metal and elemental fuels and other additives in energetic materials, or by themselves, contribute significantly to primary smoke (see "secondary smoke").
Producibility	The elements of a design by which a product or a commodity, while meeting all of its performance objectives within the design constraints, may be produced in the shortest total time, at the lowest cost, with the most readily available materials using the most advantageous processes and assembly methods. (U.S. Army, AMC, definition.)
Progressivity	The rate of increase of the burning rate, or of the surface area, of a burning propellant (see "Propellant grain").
Propellant grain	A single piece of propellant, whose dimensions may vary from a few millimeters to several meters (known as the *configuration* for single grains or the *granulation* for charges consisting of more than one grain). Configurations are changed to vary the exposed surface of grains and thus vary the burning surface. A grain that maintains a constant burning surface has a *neutral* configuration; a grain whose surface area or burning rate increases has a *progressive* configuration; a grain whose burning surface decreases has a *degressive* configuration.
Pyrophorics	See "Military Pyrotechnics."

Reduced smoke	A descriptor for propellants that have been tailored to produce less smoke than standard formulations of aluminum and ammonium perchlorate (see "smoky"). They may be classified by AGARD as either class AC or BC.
Rocket motor	A non-air breathing reaction propulsion device consisting of a "thrust" or combustion chamber in which formulations of solid fuels, oxidizers and additives are burned and expanded through an exhaust nozzle.
Secondary smoke	Smoke that results from the interaction of propellant or pyrotechnic exhaust gases with ambient water to form droplets that condense on submicron atmospheric particles. Low temperatures, high humidity, and acid vapors, such as the HC1 combustion products of ammonium perchlorate, all contribute to secondary smoke formation.
Seeker	A device that orients a munition's sensor to survey, acquire, lock-on, and track a target.
Sentient (or Correlated)	A descriptor for a "brilliant" munition that is aware of itself and its surroundings; for example, a brilliant munition that responds to its environment, or communicates with others among the same payload or salvo to share out the targets and maximize interception.
Signature	Any or all of the properties of a gun or a rocket motor that may be used for the detection, identification, or interception of the device or its launch site. Plume signature characteristics include smoke, radiation emissions, visibility, radar absorption, self-absorption, etc.
Smart munition	A "many-on-many" munition with a minimal target selection capability that does not require an operator in the loop. There are two prime categories: terminally guided ("hit-to-kill") and sensor fuzed ("shoot-to-kill").
Smoke	A deliberate obscurant (qv) or colored signal, or the inadvertent effluent from the combustion of a pyrotechnic or propellant, any of which is made visible by light scattered or absorbed by condensed or liquid particulates. A component of the signature of a gun or missile propellant.

Smokeless	A nitrocellulose-based gun or rocket propellant as distinct from a relatively "smoky" black powder explosive. The term originally (late 19th century) applied to a single-base NC propellant, but later also became applied to double- or triple-based propellants to which additives had been incorporated to reduce smoke.
Smoky	A particular term used to describe rocket and missile propellants with high aluminum and ammonium perchlorate contents. An AGARD class CC composition.
Solids loading	The percentage of particulate matter in the total weight/volume of a propellant composition or grain. The solids loading attainable for a given fuel-oxidizer particulate composition depends on the binder and additives used to form a grain. Missile propellants are commonly rated in terms of a weight percentage, gun propellants in terms of a volume percentage.
Stabilizers	Substances used in explosive formulations to improve their shelf-life.
Thrust	The force that propels a body or the rate of change of momentum of a burning propellant.
Turnkey plant	As defined in this handbook, consists of all the hardware, software, technical data, and technical assistance necessary for the installation of a complete operating facility for the production of the commodity, a chemical substance, at defined production rates and to specified product qualities. Hardware consists of all the equipment, components, control valves, instruments, reaction vessels, feed lines, and explosion-proof barriers necessary for the conduct of the unit operations of the overall production process, whether the items are assembled or disassembled for transportation. The plant may be designed for installation at a prepared site that includes locally constructed and installed explosion proof barricades.

APPENDIX A
INDEX OF DATA SHEETS

APPENDIX B
INDEX OF PREFERRED SUBSTANCE NAMES

APPENDIX C
INDEX OF SYNONYMS

REPORT DOCUMENTATION PAGE

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13. ABSTRACT *(Maximum 180 words)*

This handbook is a distillation, in data sheet format, of information about substances not widely available outside of the United States and its NATO allies that are considered to be critical for the development of advanced weapons and munitions systems. It is intended as a desktop handbook for Customs officers; licensing, security, and classification officials; and research development, and engineering personnel. There continue to be many omissions and gaps in day-to-day knowledge of the listed substances. Further, it is not known whether some of the substances are currently used—or whether they will be used in the future—in any weapons systems. The template has been designed to permit the ready expansion or elimination of entries as appropriate. It is apparent even from the summary data sheets that many of the listed energetic materials are increasingly available, or at least offered for sale, in both NATO and developing countries.

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